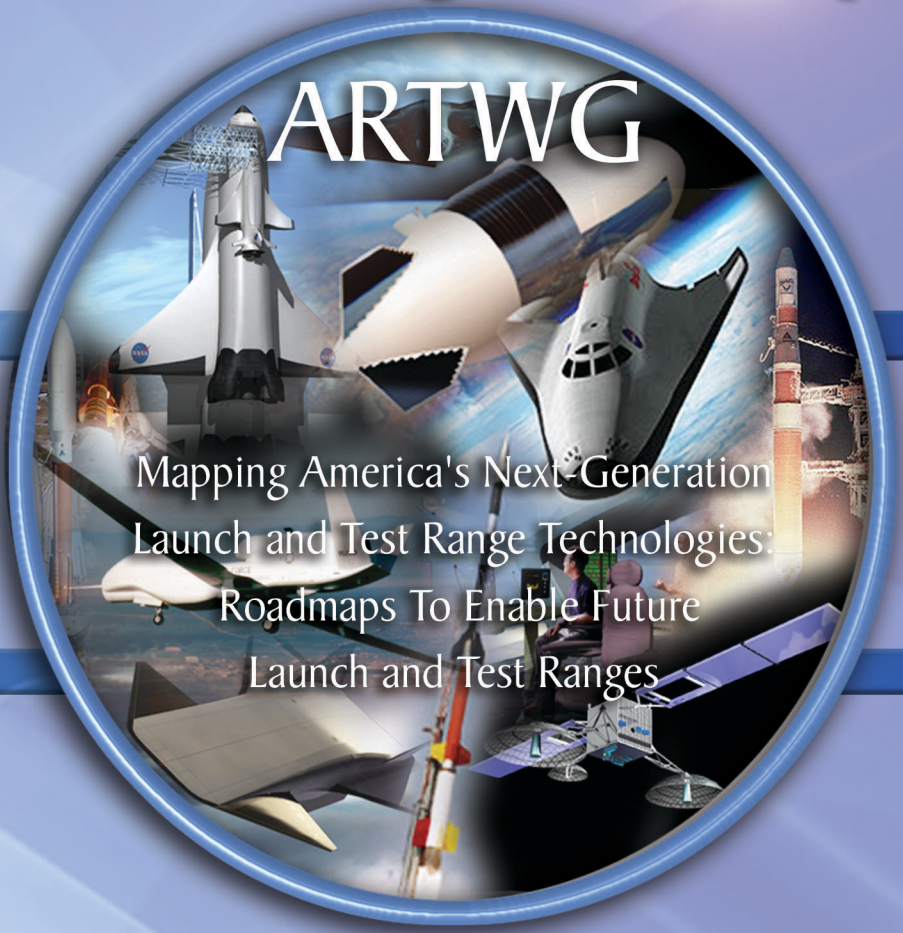
EXECUTIVE SUMMARY

Advanced Range Technologies Working Group



March 2004

Co-Chairs
NASA Kennedy Space Center
Air Force Space Command

U.S. AIR FORCE

Advanced Range Technologies Working Group (ARTWG)

Mapping America's Next-Generation Launch and Test Range Technologies:

Roadmaps To Enable Future Launch and Test Ranges

Co-Chairs: NASA Kennedy Space Center
Air Force Space Command

Foreword

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Advanced Range Technologies Working Group Membership

30th Space Wing
45th Space Wing
ACTA Inc.
Aerospace Corporation
Aerospace Industries Association
Aerospace States Association
Aero-Thermo Technology, Inc.
Aim8 Product Development Inc.
Air Force Research Laboratory
Air Force Space Command
Air Traffic System Requirements Service
Alliant Techsystems Inc.
All Points Logistics, Inc.
Altech Services, Inc.
Analex Corporation
Anteon Corporation
Applied Meteorology Unit
Applied Physics Lab
APT Research
ASRC Aerospace
ATK Tactical Systems
Avmet Applications International
BAE Systems
Boeing
Booz Allen Hamilton
California Space Authority
CMC Electronics
Coleman Aerospace
Command & Control Technologies Corp
Computer Sciences Raytheon
Custom Manufacturing & Engineering, Inc.
Delta Velocity Corporation
Department of Commerce (DOC)
Department of Transportation (DOT)
DFI International
Dynacs Engineering Co.
Dynamac Corp.
Ebertech Electronic Solutions
Edwards Air Force Base
Elgin Air Force Base
ENSCO, Inc.
Federal Aviation Administration
Florida Air National Guard
Florida Space Authority
Harris Corporation
Hernandez Engineering
Honeywell Space Systems
Indyne
Infoware Systems Inc.
Institute for Defense Analysis
Interface and Control Systems
International Consortium for Telemetry Spectrum
ISDR
ITT Industries, Systems Division
Kelley Logistic Support Systems
Kirtland Air Force Base
Kistler Aerospace
Knowledge Based Systems Inc.
KT Engineering
L3 Communications
Le Bas International
LJT and Associates
Lockheed Martin
Loral Space and Communications
Microcosm, Inc.
MITRE
NASA Ames Research Center
NASA Dryden Flight Research Center
NASA Glenn Research Center
NASA Goddard Space Flight Center
NASA Jet Propulsion Laboratory
NASA Johnson Space Center
NASA Kennedy Space Center
NASA Langley Research Center
NASA Marshall Space Flight Center
NASA Stennis Space Center
NASA Wallops Flight Facility
National Coalition of Spaceport States
National Oceanic and Atmospheric Administration
Navair
Naval Ordnance Test Unit (NOTU)
NAWC-WD Pt Mugu
Nebraska Space Grant Consortium
New Mexico State University
Nnorth Consulting
North Carolina A&T State University
Northrop Grumman
Optimal Synthesis, Inc.
Orbital
Peterson Air Force Base

Reagan Test Site
Reliable System Services Corporation
RSO Inc.
RSS Corp.
RTI International
RTS
SAIC
SBC Global
Schafer
Scitor
SGS
Sigmatech
SI International
Southern Marketing
SPACE.com
Spaceflight Meteorology Group
Space Information Labs, Inc.
SRI International
SRS Information Services
Sverdrup Technologies
The Madewell Group
Tinker Air Force Base
Titan Systems
TYBRIN
United Paradyne Corporation
University of Alaska at Anchorage
University of Arizona
University of Central Florida
University of Nebraska Lincoln
University of Oklahoma
U.S. Air Force Headquarters
U.S. Navy
Vandenberg Air Force Base
Veridian
VidNet Systems, Inc.
Virginia Space Flight Authority
Wallops Flight Facility
White Sands Missile Range
Wright-Patterson Air Force Base
Zel Technologies, Inc.
ZHA Inc.

Advanced Range Technologies Working Group (ARTWG) Leadership Team

ARTWG Co-Chairs: **Darin Skelly, NASA Kennedy Space Center, Florida**
Major Debra Fogle, HQ AFSPC/XPX, through May 2003
Major Jennifer Draper, HQ AFSPC/XPXZ

Facilitator: **Timothy Kotnour, Ph.D. Associate Professor, Industrial and Systems Engineering, University of Central Florida, Orlando, Florida**

ARTWG Subgroup Co-Chairs:

Tracking and Surveillance
Lt. Col. Rembert Schofield, 45 RANS/FLANG, Cape Canaveral AFS, Florida
Victor Villhard, Booz Allen Hamilton, Colorado Springs, Colorado

Telemetry
Jim Shaver, NASA Kennedy Space Center, Florida
Dr. Sandra Slivinsky, Air Force Research Lab, Kirtland AFB, New Mexico

Communication Architecture
Erik Denson, NASA Kennedy Space Center, Florida
Karen Barker, Lockheed Martin, Bethesda, Maryland

Range Command and Control Systems
Steve Swichkow, NASA Kennedy Space Center, Florida
Dr. Paul Phister, Air Force Research Lab, Rome, New York

Decision Making Support
Kathy Potter, NASA Kennedy Space Center, Florida
Marti Fallon, Aerospace Corporation, Colorado Springs, Colorado

Planning, Scheduling, and Coordination of Assets
Marty Waldman, 30th Space Wing, Vandenberg AFB, California
Darren Buck, United Space Alliance, Cape Canaveral, Florida, through May 2003
William Nelson, Booz Allen Hamilton, Santa Maria, California

Weather Measurement and Forecasting
John Madura, NASA Kennedy Space Center, Florida
Rick Heuwinkel, FAA/ARS Washington, D.C. through May 2003
Joann Ford, FAA/ARS, Washington, D.C., since May 2003

Additional assistance with development of report:

- **California Space Authority**
- **Booz Allen Hamilton**

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EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

On February 8, 2000, the White House released a report titled, "The Future Management and Use of the U.S. Space Launch Bases and Ranges." The report recommended "the Air Force and NASA should develop a plan to examine, explore, and proceed with next-generation range technology development and demonstration, with a focused charter to improve safety, increase flexibility and capacity, and lower costs for reusable and expendable launch vehicles." In response to this recommendation, NASA and the United States Air Force (USAF) established the Advanced Range Technologies Working Group (ARTWG).

PURPOSE

The purpose of the ARTWG is to cooperatively develop a national vision through a broad coalition of space transportation industry experts and stakeholders. The ARTWG provides a forum and framework to formulate a strategy and identify enabling technologies needed to achieve that vision. Membership includes NASA Centers/Programs, private industry, current and future spaceport and range customers, operators and developers (including existing and emerging launch services providers), commercial and emerging spaceports, academia, states, the Federal Aviation Administration (FAA), Department of Defense (DoD), and Department of Commerce (DOC). The ARTWG was chartered to:

- Identify space launch and test range technology needs for a broad spectrum of ranges.
- Develop a roadmap (plan) that contains project options for the development and demonstration of range technologies that will meet the needs of the existing and future ranges established by Federal policy or by other U.S. entities.
- Develop plan approaches and options for reaching the next-generation advanced ranges of the future.

The ARTWG focus includes:

- Orbital and suborbital ranges tracking expendable and reusable launch vehicles.
- Government and nongovernment, existing and future ranges.

The ARTWG has subdivided the "Range" into seven technical focus areas, which include:

- Tracking and Surveillance
- Telemetry
- Communication Architecture
- Range Command and Control Systems (RCCS)
- Decision Making Support
- Planning, Scheduling, and Coordination of Assets
- Weather Measurement and Forecasting

The Advanced Spaceport Technologies Working Group (ASTWG) addresses spaceport (ground launch site) technologies and also pulls the Cross-Cutting Architecture Roadmaps that were consistent in many technology focus areas. The ARTWG is coordinating its activities with the ASTWG so that two key areas of the Macro Space Transportation System, Range and Spaceport, are addressed (see Figure 1).

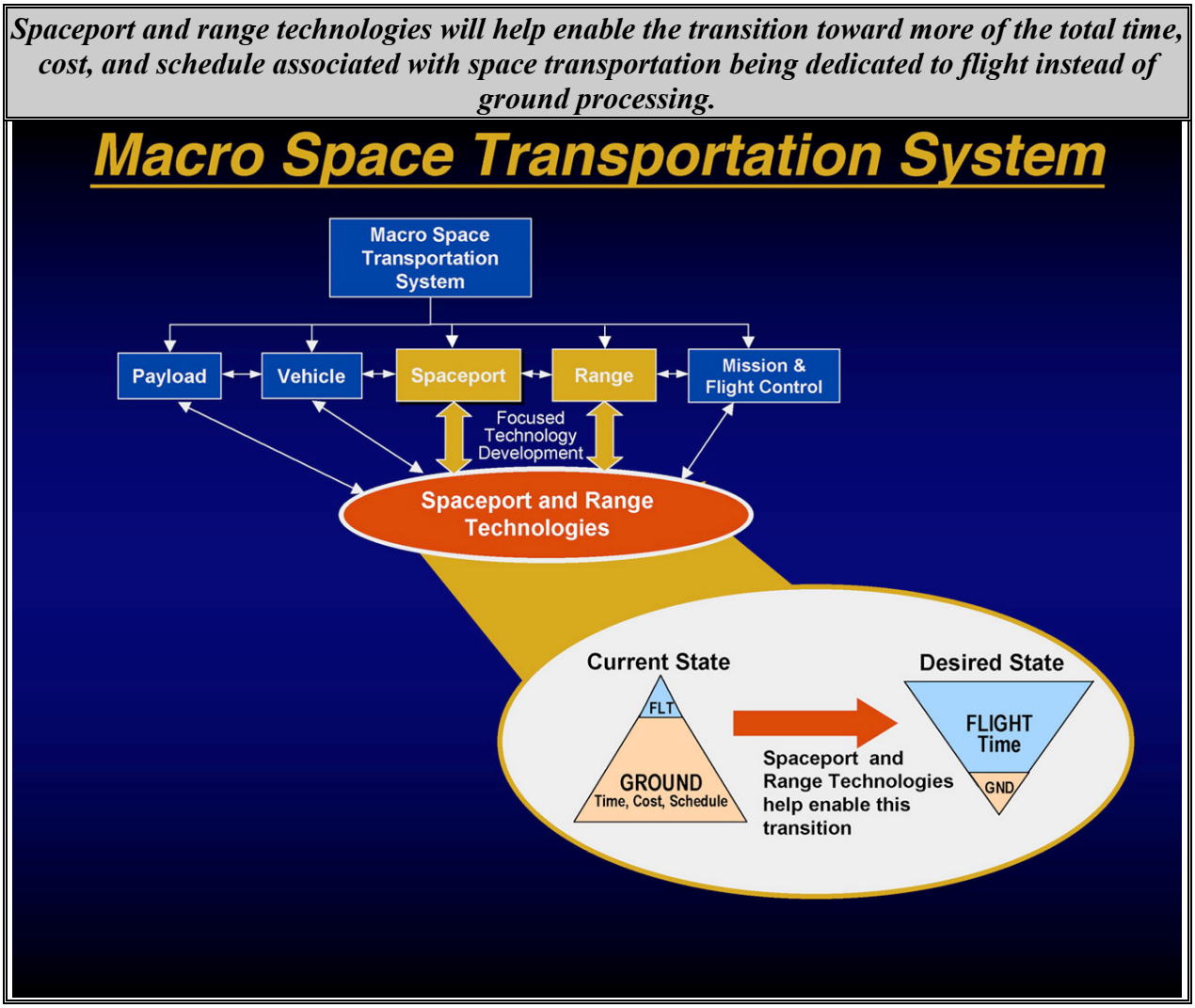

Figure 1. Spaceport and Range Elements of the Macro Space Transportation System

SCOPE

Future next-generation range functions will be driven by the needs of various range stakeholders, including spaceport operators; launch vehicle and payload designers, developers, and operators; range administrators; and oversight and regulatory arms of the Federal government. Each stakeholder group has its own set of needs today and for the future. Some of these needs overlap, including the desire for reliable, responsive, and cost-effective range operations. Others are more unique to individual stakeholder groups. For example, DoD is more interested than some of the other stakeholders in the ability to responsively launch and operate spacecraft in orbit, requiring responsive range support as well. Figure 2 summarizes the results of the

ARTWG's assessment of the various range stakeholders' current and future needs for range capabilities.

A variety of range stakeholders in several categories has some common and unique needs today and for the future.

Affordable Access to Space

Common Needs: safety, security, resource protection (including physical security, force protection, and information assurance), lower costs, greater flexibility, increased capacity and concurrent operations, shortened flight plan approval, effective data handling and information systems.

Stakeholder Group	Stakeholders	Today's Needs	Future Needs
Spaceports (Customer)	• Federal Spaceports • State Spaceports • Commercial Spaceports • Developing Spaceports	• Flexible, robust, and efficient systems that can support high-flight rates • Shared-use infrastructure that supports concurrent operations • Cost-effective systems • Opportunities to create viable new spaceports • Effective master planning	• Cost-effective • Ability to access a variety of orbits • Effective master planning • Multimode transportation • Effective data handling and information systems

Launch Vehicle Designers, Developers, Providers, and Operators (Customer)	• Government
	  • Military
	  • Civil
	  • Other
	• Commercial
		• Responsive and robust range
		• Engineering data during development
		• Reliable and flexible launch dates
		• Effective data handling and information systems
		• Effective regulatory coordination
			• Efficient, cost-effective, responsive, and robust range
			• Evolving regulatory process in space with vehicle developments
			• Less impact to vehicle systems
			• Vehicles with short turnaround time
			• Simplified/standardized system interfaces

Payload Providers and Developers (Customers)	• Government
	  • Military
	  • Civil
	  • Other
	• Commercial
	• Nonprofit (e.g., academia)
		• Responsive and robust range
		• Reliable and flexible launch dates
		• Rapid access to space (DoD)
		• Highly reliable vehicles
		• Increased standardization between vehicle and operations
			• Responsive and robust range
			• Large surge launch rate capability
			• International range compatibility
			• Short notice launch and landing world wide
			• Improved coordination

Range Administrators (Owners and operators)	• Military • Civil • Other	• Consistent compliance processes • Increased automation • Low turnaround time between launches • Highly reliable vehicles	• Reduced asset costs • Full integration with FAA ATC, space surveillance network • Interoperability between ranges • Align range to support routine operations or test and evaluation • Global coverage
Federal and State Governments (Funding and oversight)	• U.S. Government • State Governments • Local Governments	• Economic competitiveness • Environmental stewardship • Standardized and simplified Government policies • Workable, effective regulations	• Routine space transportation • Appropriate regulatory processes that meet public safety and commerce needs • International agreement on Range operations

Figure 2. U.S. Range Stakeholders' High-Level Needs

Two primary types of missions are likely to require support from space launch and test ranges in the future. They are:

- Space Launch and Recovery Operations – Including, for example, expendable launch vehicle (ELV), Space Shuttle, and reusable launch vehicle (RLV) launch and recovery operations, including suborbital RLVs and entrepreneurial systems, for a wide variety of national security, civil, and commercial missions, and launches and recovery operations involving the Orbital Space Plane (OSP) and Next-Generation Launch Technology (NGLT) being developed under NASA's Space Launch Initiative (SLI), part of its Integrated Space Transportation Plan (ISTP). In the far term, it is envisioned that suborbital RLVs (SRLV) will emerge and also "drive" the space-launch industry market.

- Test and Evaluation (T&E) Mission – Including, for example, aeronautical flight testing of civil and military aircraft and flight systems, various types of guided missiles, and unmanned aerial vehicles (UAVs) with a variety of possible applications; intercontinental ballistic missile (ICBM) and submarine-launched ballistic missile (SLBM) T&E missions; orbital and suborbital flight demonstrations for DARPA's operationally responsive FALCON Program, Ballistic Missile Defense Systems (BMDS) T&E, and flight testing of hypersonic missiles, propulsion systems, and vehicles as part of the National Aerospace Initiative (NAI) - a cooperative effort across DoD and NASA. Although this mission is not the primary focus of the ARTWG, the technologies being identified are synergistic with the advancements needed in this community (see Figure 3).

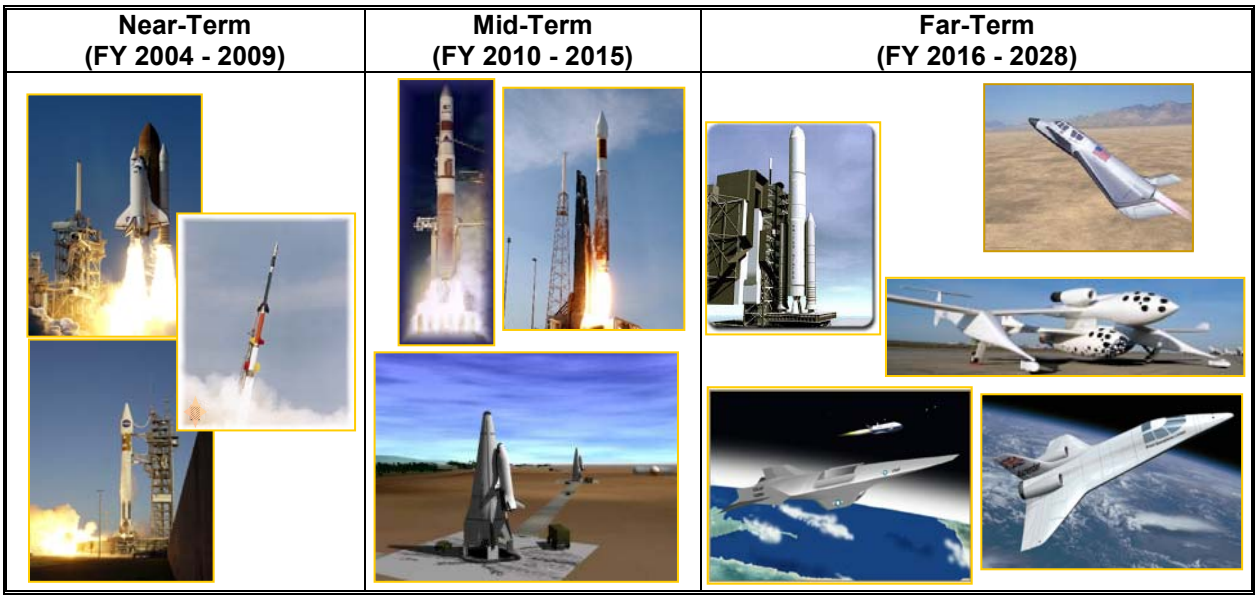

Figure 3. Examples of Future Space Launch Vehicles Requiring Range Support

While space launch and T&E missions are challenging for the space launch ranges to support, the most "stressing" technical challenges will be for future SRLVs, and the currently planned T&E activities associated with the planned flight testing of ballistic missile defense systems involve multiple high-speed targets and interceptors being launched from multiple locations, including ships and aircraft, at widely dispersed geographic locations.

APPROACH

Recognizing the ARTWG as an interagency program formulation effort that involved a diverse set of stakeholders, ARTWG followed a three-pronged approach to developing the ARTWG Technology Plan (see Figure 4). The three efforts focused on:

1. Build and follow a Strategic Program

2. Build the ARTWG Technology Plan

3. Build the ARTWG Community

ARTWG undertook an interagency program formulation effort with a diverse set of stakeholders by following a three-pronged approach to developing Technology Roadmaps.

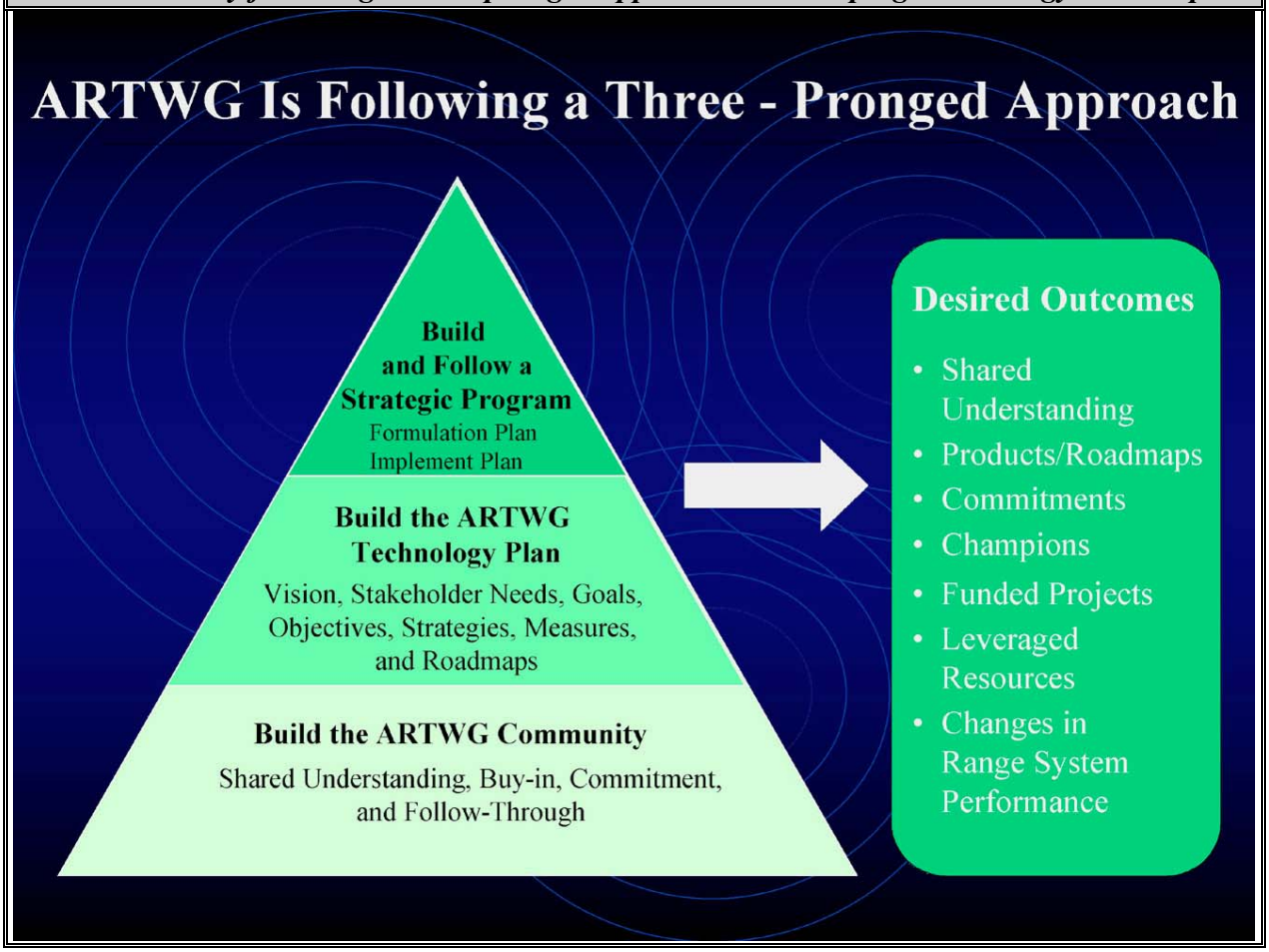

Figure 4. ARTWG's Three-Pronged Approach

To accomplish the scope of the ARTWG charter, ARTWG developed an integrated approach to ensure all interested stakeholders would be able to participate. To build a broad level of involvement, the ARTWG undertook the following actions:

- Implemented a shared leadership structure across agencies and organizations.
- Invited participation within the working groups.
- Conducted open meetings, conferences, and workshops.

The ARTWG roadmaps and recommendations will be reviewed by senior Government representatives, including:

- Senior Steering Group - Representatives from NASA, FAA, Office of Secretary of Defense (OSD), and USAF to provide guidance to the Executive Steering Committee and the ARTWG Leadership Team. Members will be appointed by NASA and the USAF.

- Executive Steering Committee - Senior Representatives from Federal organizations, such as NASA, USAF, FAA, OSD, and others as appointed to provide senior agency guidance and recommendations.

It is envisioned that the products of the ARTWG will become the national roadmaps for the development of future next-generation space launch and test ranges. All ARTWG efforts were focused on first defining the vision for future range capabilities, then establishing goals and objectives for each function and subfunction within each of the seven technical focus areas. Next, each subgroup outlined a series of technical challenges and approaches to address each challenge. The roadmaps that resulted from the process of defining goals (G), objectives (O), technical challenges (TCH) and approaches (A) are referred to as GOTCHA charts.

VISION FOR IDEAL FUTURE SPACE LAUNCH AND TEST RANGES

Over the past 25 years, a variety of studies have assessed the advantages of various alternative range architectures and approaches. Most recently, the Extended Range Concept Definition Study - sponsored by the California Space Authority and conducted between September 2001 and September 2002 by Booz Allen Hamilton under contract with DoD's Information Assurance Technology Analysis Center - built on this body of range-related studies. It described and evaluated various options and recommended a next-generation space launch and test range based on evaluation criteria established through interaction with range stakeholders. The ARTWG adopted the elements of this study in the course of defining its vision for the future.

A primarily space-centric range supplemented by mobile assets would improve the adaptability and flexibility of future ranges in terms of their ability to accommodate higher- or lower-than-projected workload, provide expanded geographic coverage to a global scale, and provide the ability to increase capacity by using mobile assets for supplemental coverage where and when needed (Figure 5). By leveraging synergistic technologies and approaches and by sharing use of systems, such a future range could be less expensive to operate and maintain.

A primarily space-centric range supplemented by mobile range assets would improve adaptability, flexibility, and geographic coverage while providing capacity as needed.

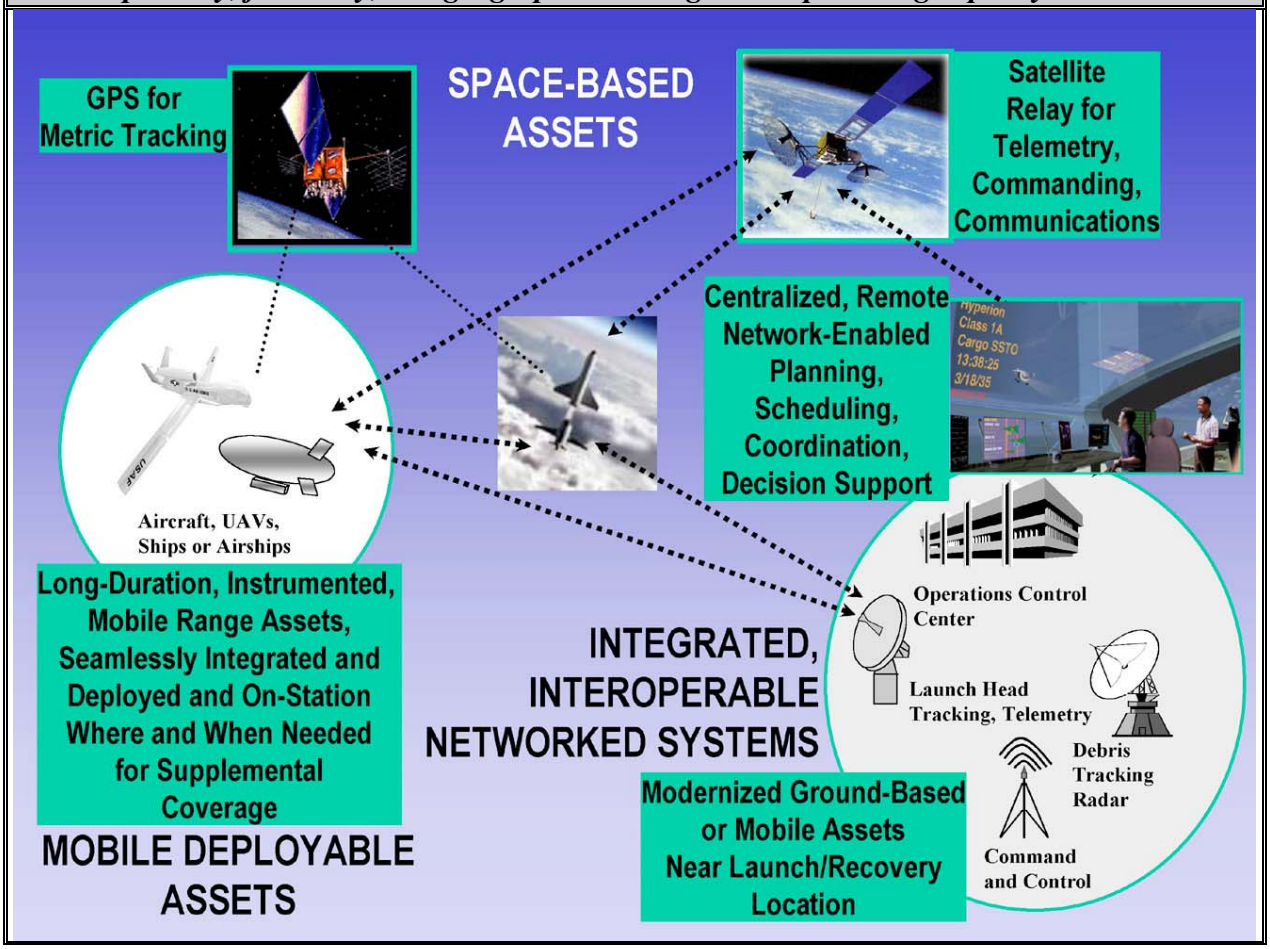

Figure 5. Vision for Future Global Launch and Test Range Architecture

Such a future range would use a global positioning system (GPS) for tracking data and communication satellites for relaying telemetry and commands between flight vehicles and range assets, as well as for communications between and among range control centers and range assets. The vision would be to maintain a robust, two-way data link with flight vehicles for both telemetry and commanding. Such a future range would also incorporate modernized ground-based or mobile range assets to provide up-range tracking of debris and telemetry and commanding capabilities required to meet safety standards without the time delay associated with using satellites. Broadband relay satellites would be used as the primary telemetry and commanding capability for down-range operations requiring hemisphere- or global-scale range coverage, where the time delay can be accommodated without adversely impacting the safety of range-supported operations. Mobile range assets would be used to provide additional flexibility to supplement range coverage and capabilities in cases when specific missions require particular range support functions that could not be met by satellites alone.

Developing such a future range architecture with both space-based and mobile range assets would improve adaptability, flexibility, and geographic coverage of range capabilities along with expanded capacity as needed to meet projected missions while enabling incremental development and technology demonstrations at relatively low cost and risk.

ADVANTAGES OF THE FUTURE RANGE VISION

The ARTWG's vision of the ideal range for the far-term future (i.e., 25 years hence) would provide substantial advantages over today's ground-based, fixed-location range architectures in terms of the following desirable characteristics:

a. Reliable, available, operable, and maintainable

b. Adaptable to fit the mission

c. Flexibility/capacity

d. Integrated with other systems

e. Economical

f. Integrated range system

g. Customer friendly

CAPABILITY AND TECHNOLOGY ROADMAPS

The purpose of the ARTWG is to define a national technology strategy to enable development of future space launch and test range capabilities relying primarily on space-based assets, supplemented by mobile range assets (e.g., UAV, high-altitude airship [HAA]) as needed, to meet future mission needs. Each ARTWG subgroup developed both a capability roadmap to establish performance goals and objectives over time and a technology roadmap. Figure 6 summarizes the top-level goals for range system capabilities over time.

ARTWG developed a top-level summary of the performance goals over time for future ranges.

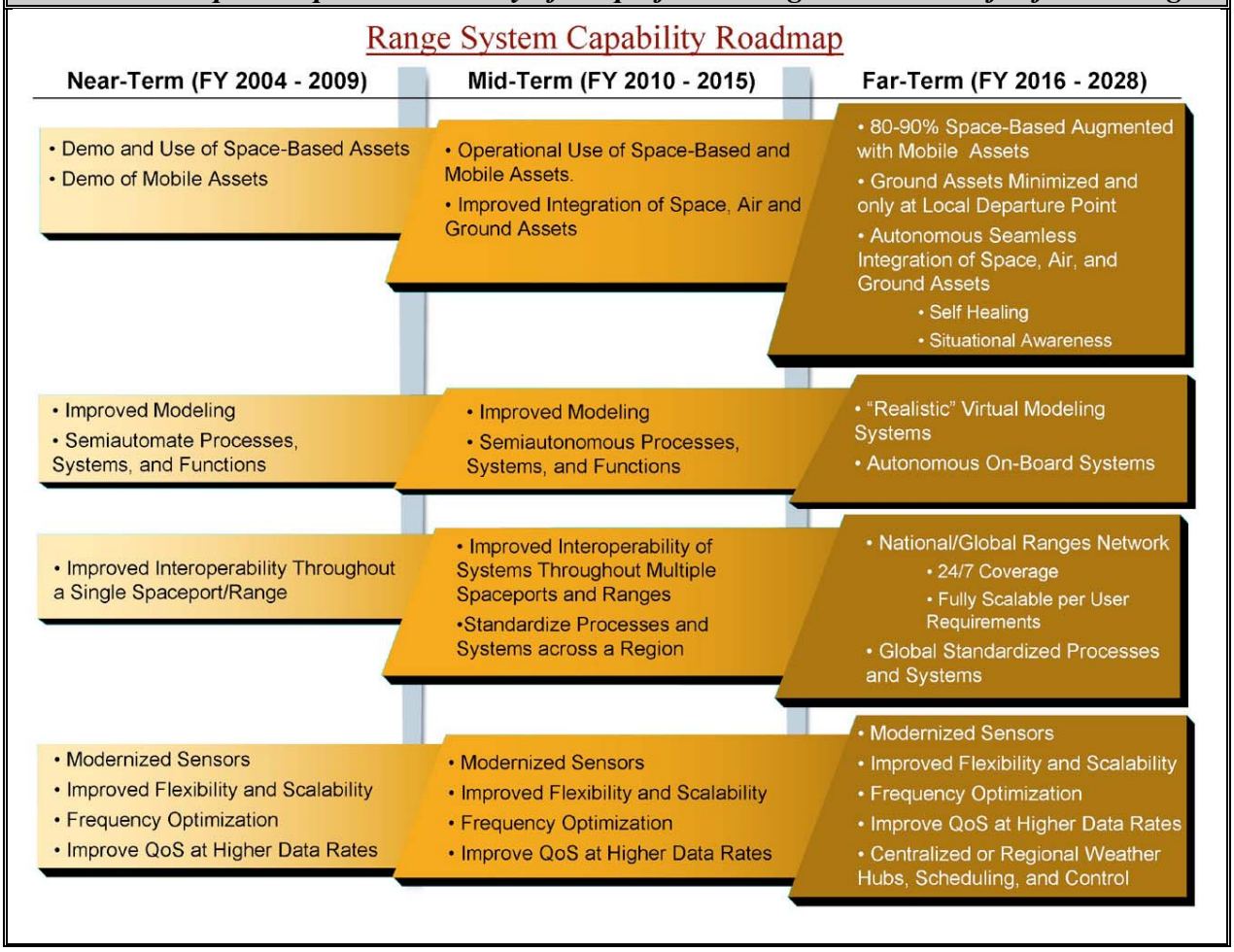

Figure 6. Range Vision: System Capability Goals Over Time

For the near-term, the primary focus is on demonstrating the utility and beginning some operational use of existing space-based (e.g., GPS, Tracking and Data Relay Satellite System [TDRSS], etc.) and mobile (i.e., UAV and HAA) assets as range instrumentation platforms. For the mid-term, the focus shifts to more integrated operational use of space-based and mobile-range assets. For the far-term, the goal is to have 80 to 90 percent of range systems on space-based platforms that can be seamlessly augmented when and where needed, with mobile or deployable assets, and modernized ground assets at departure and recovery locations.

Another major development theme is to continue improving modeling, simulations, and database systems to enable semiautomation of processes, systems, and functions through the near-term so they can evolve to semiautonomous capabilities in the mid-term. The far-term goal is to use realistic virtual modeling with intelligent systems and optimized use of autonomous systems for various functions, including onboard flight vehicle systems (if desired) and schedule deconfliction.

A third major development theme is to improve standardization, interoperability, and integration of systems throughout a single spaceport and range that is retrofitted into the National Airspace

System (NAS) for the near-term, across multiple spaceports and ranges and integrated into the NAS for the mid-term, and fully integrated across a global range network for the far-term.

Finally, several technical areas of range performance were identified for continuous improvement, including modernizing sensors, optimizing the use of frequency spectrum, and improving quality of voice/video/data communication services at higher data rates.

The ARTWG subgroups used this top-level description of the overall capability and performance goals when describing how the seven technical focus area capabilities should evolve over time.

SUBGROUP CAPABILITY AND TECHNOLOGY ROADMAPS

These products were developed as a result of intensive effort by each subgroup. Each subgroup consisted of subject matter experts from across the country, working together on an ad hoc and voluntary basis, under the direction of the subgroup co-chairs and the ARTWG leadership. They are the product of facilitated brainstorming over the course of several months, review by technical experts, and a facilitated miniretreat for each subgroup to capture the results of these brainstorming activities in a consistent format. The ARTWG leadership team addressed the areas of overlap among the technology areas identified by the subgroups and identified cross-cutting capabilities and technical approaches.

The ARTWG team recognizes that these products can and should be further refined to address inadvertent omissions and developments in current and new technologies being pursued in various Government, commercial, academic, and international environments. It is therefore the intent of the ARTWG to continue pursuing an orderly process over time to evolve and refine these products and produce future updates of the capability and technology roadmaps presented in this section. See Figures 7 through 22.

TRACKING AND SURVEILLANCE

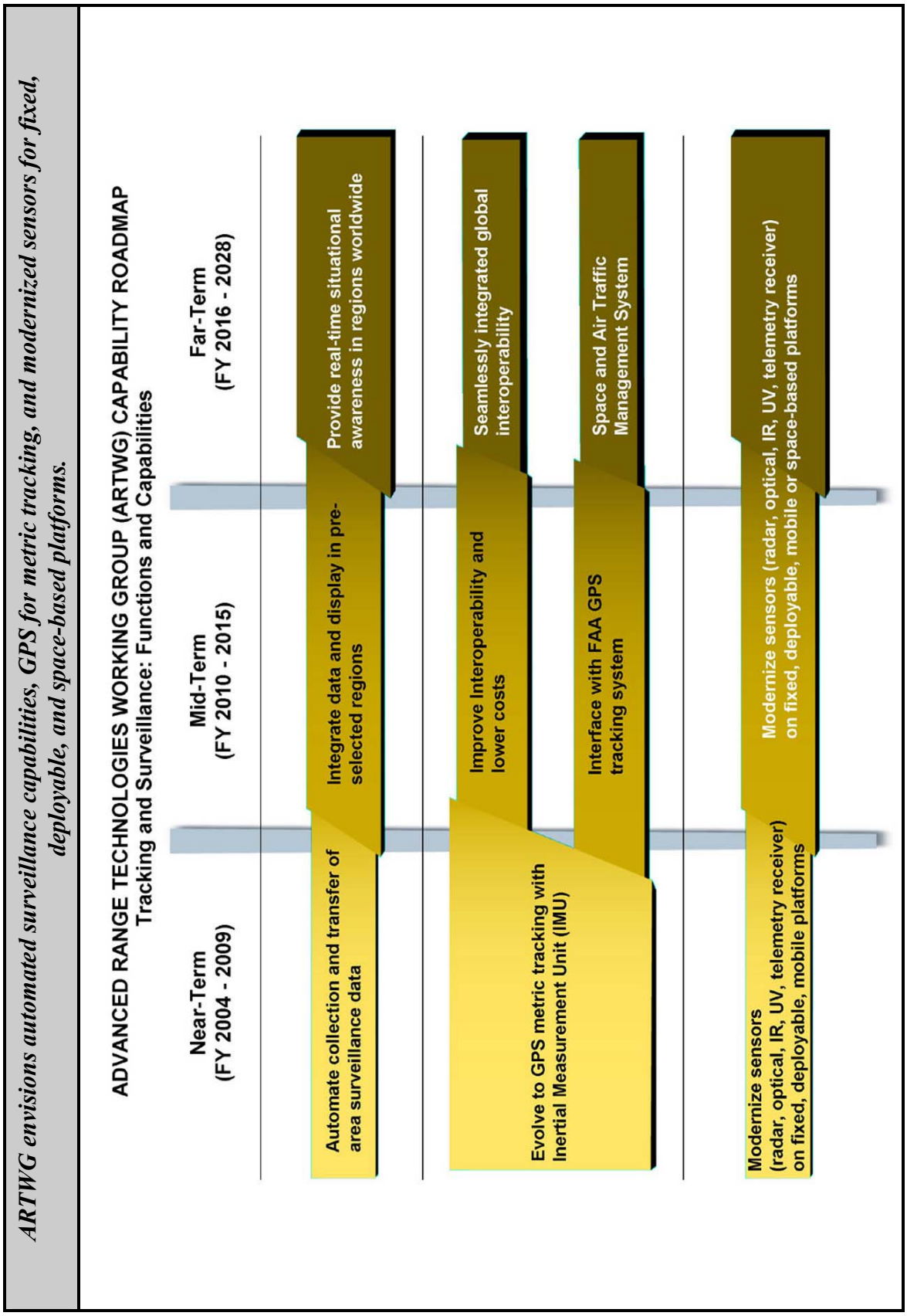

Figure 7. Capability Goals Over Time: Tracking and Surveillance

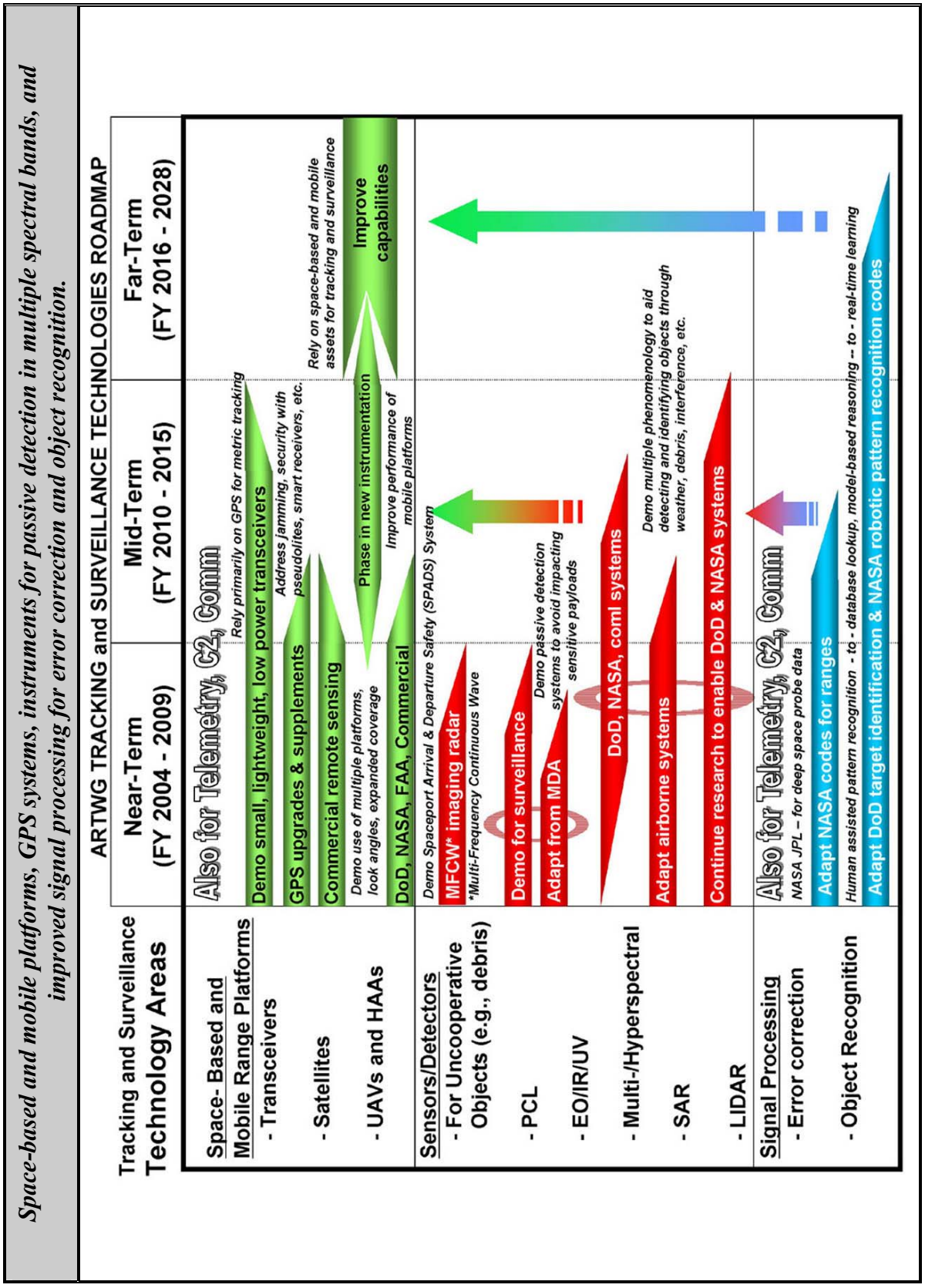

Figure 8. Technology Roadmap for Tracking and Surveillance

TELEMETRY

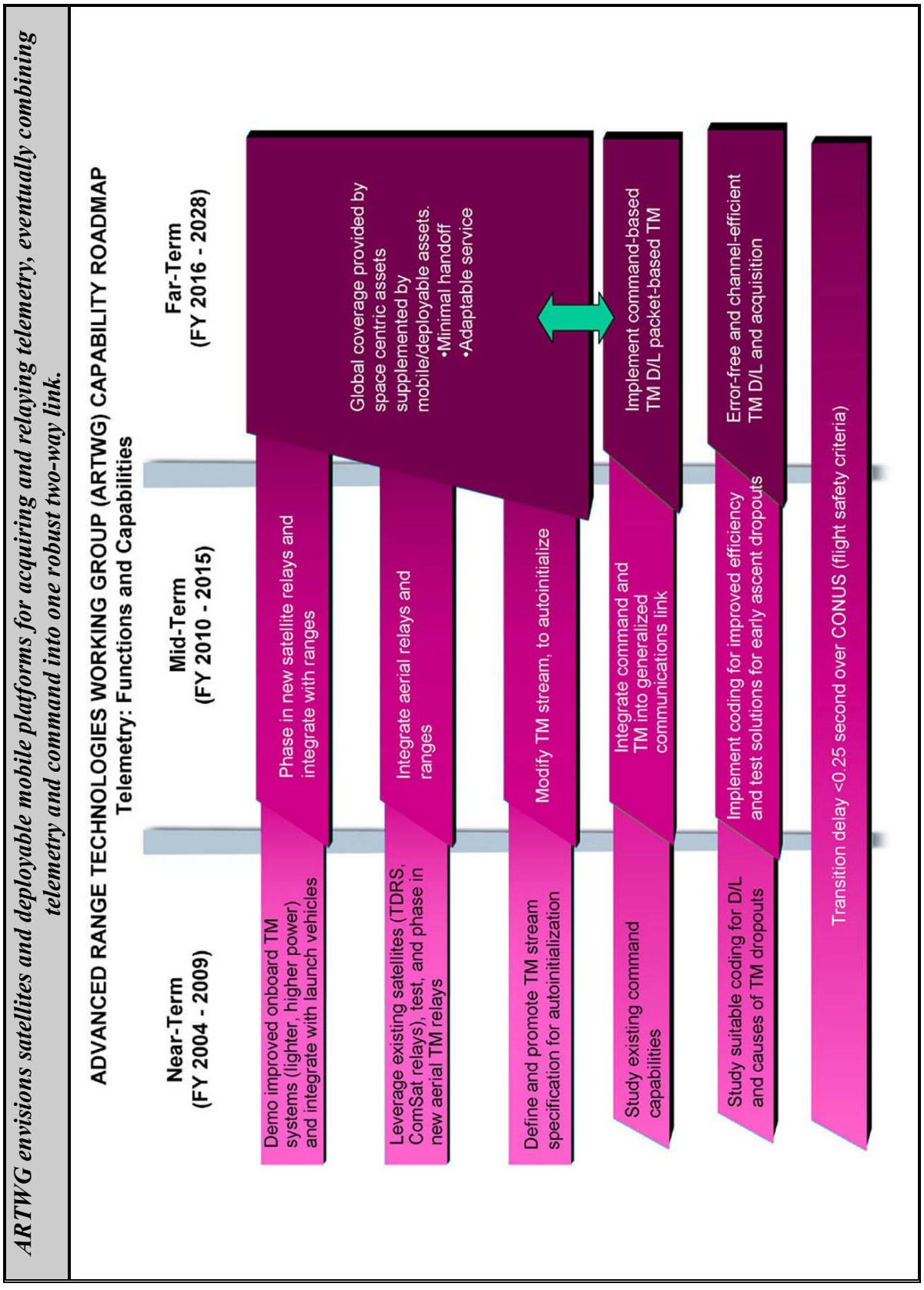

Figure 9. Capability Goals Over Time: Telemetry

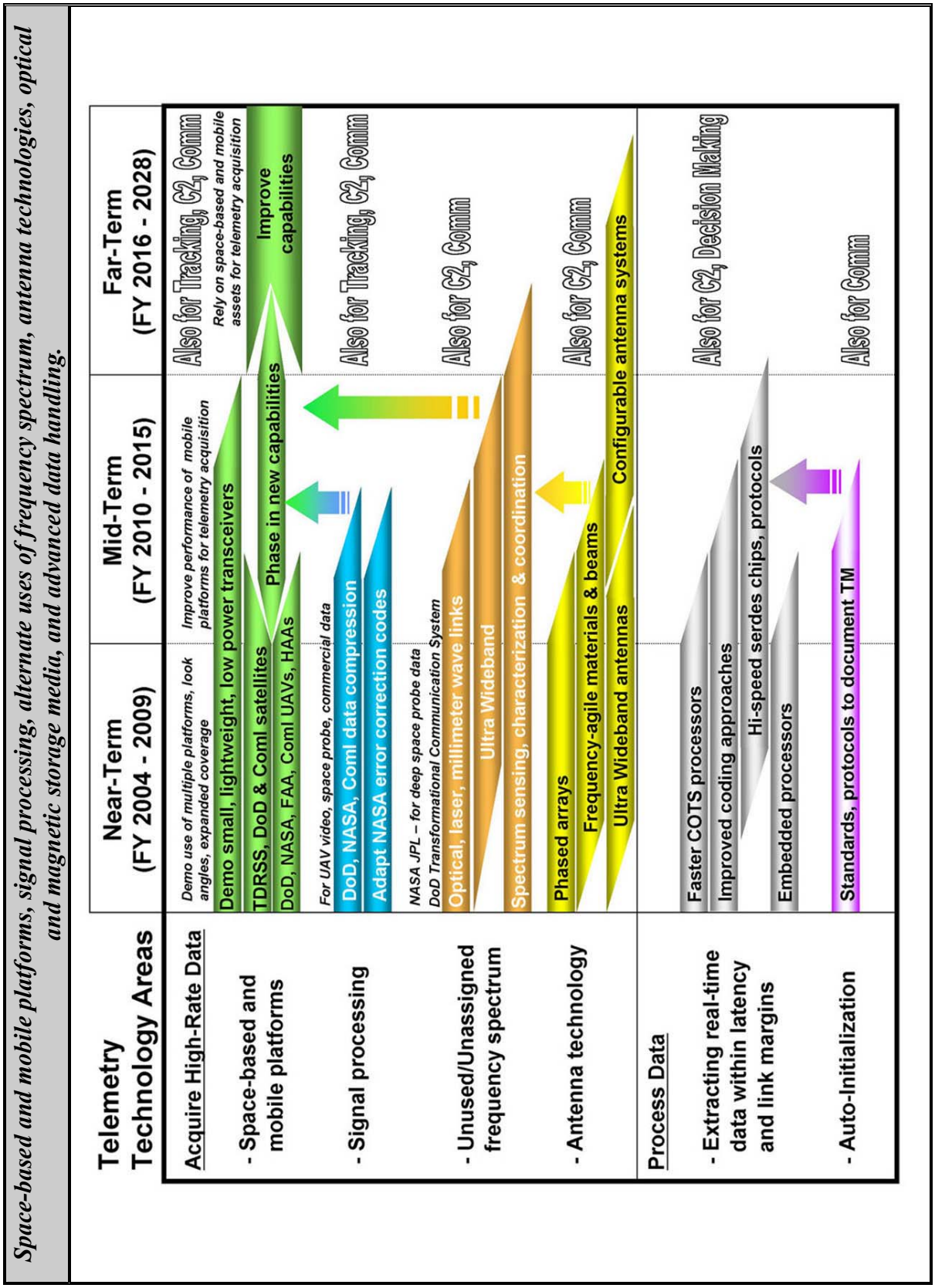

Figure 10. Technology Roadmap for Telemetry

COMMUNICATION ARCHITECTURE

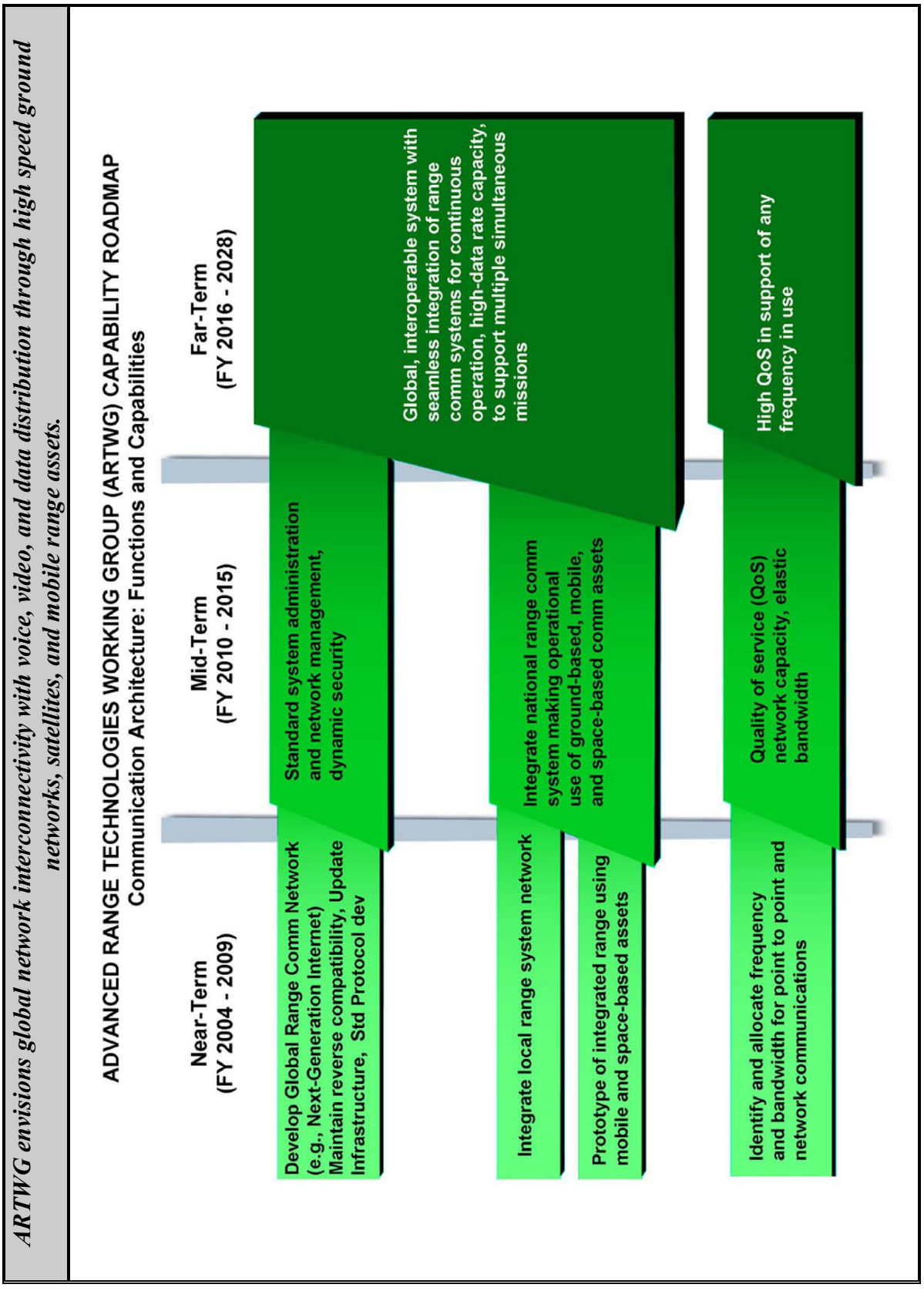

Figure 11. Capability Goals Over Time: Communication Architecture

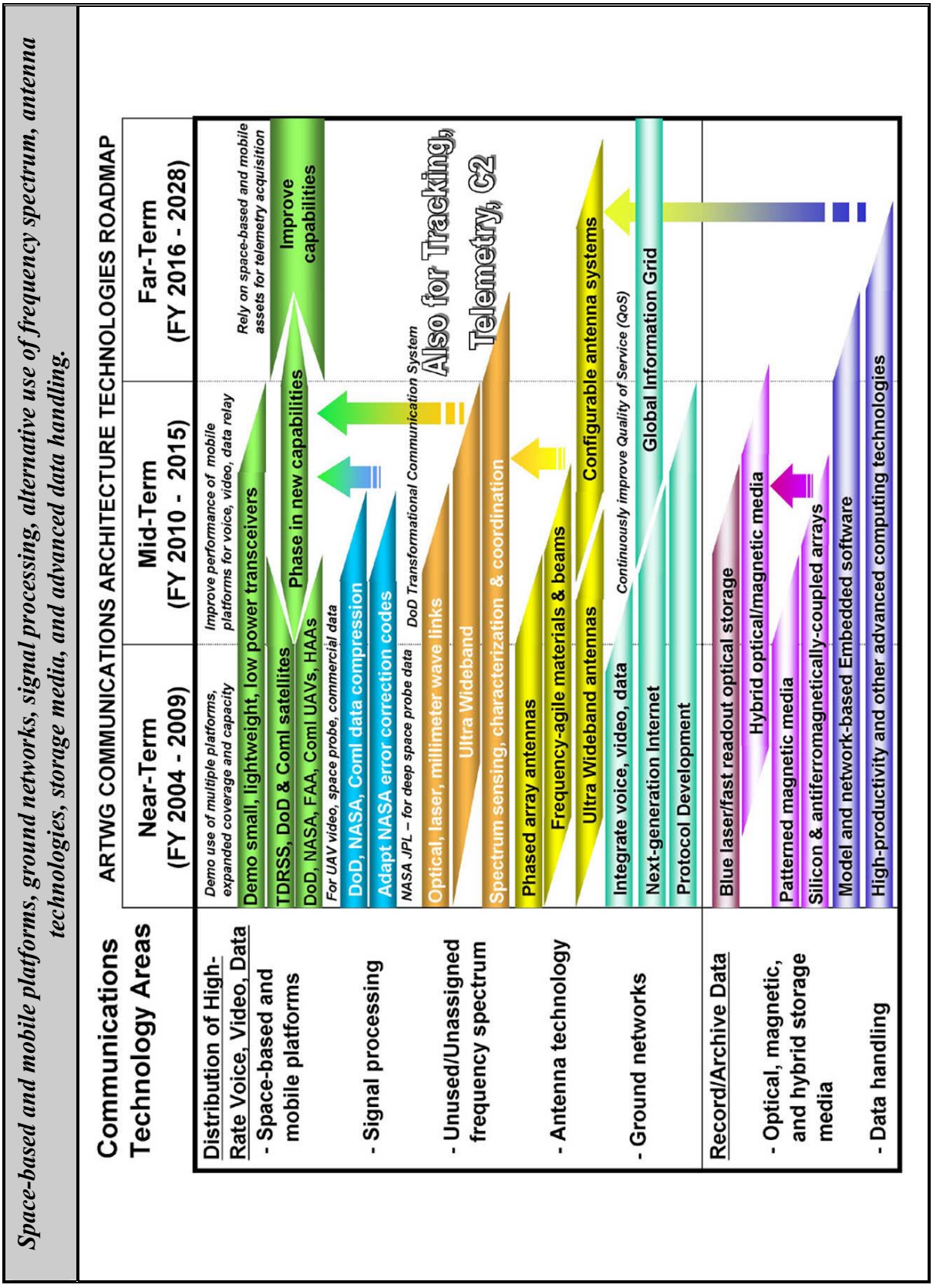

Figure 12. Technology Roadmap for Communication Architecture

RANGE COMMAND AND CONTROL SYSTEMS

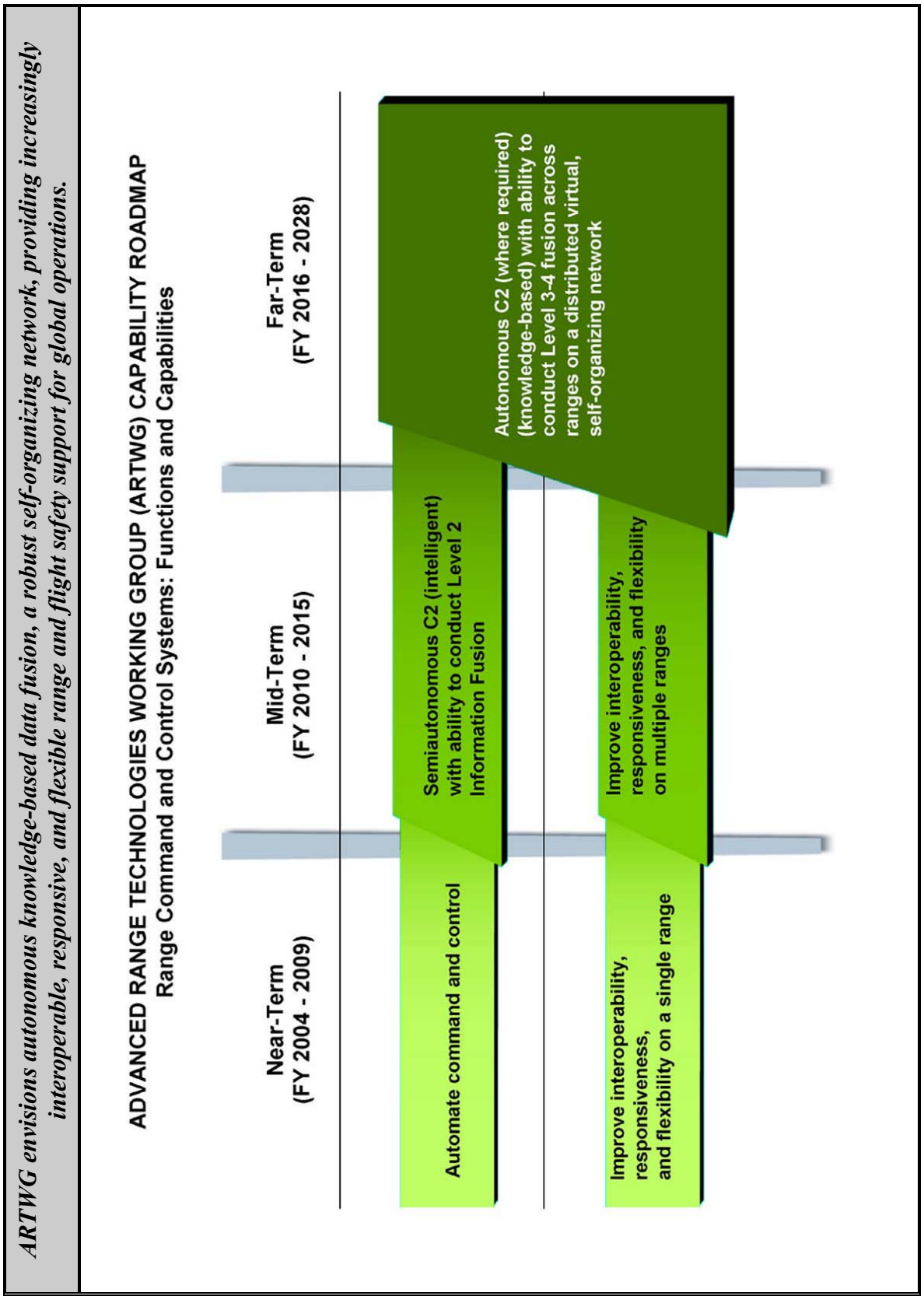

Figure 13. Capability Goals Over Time: Range Command and Control

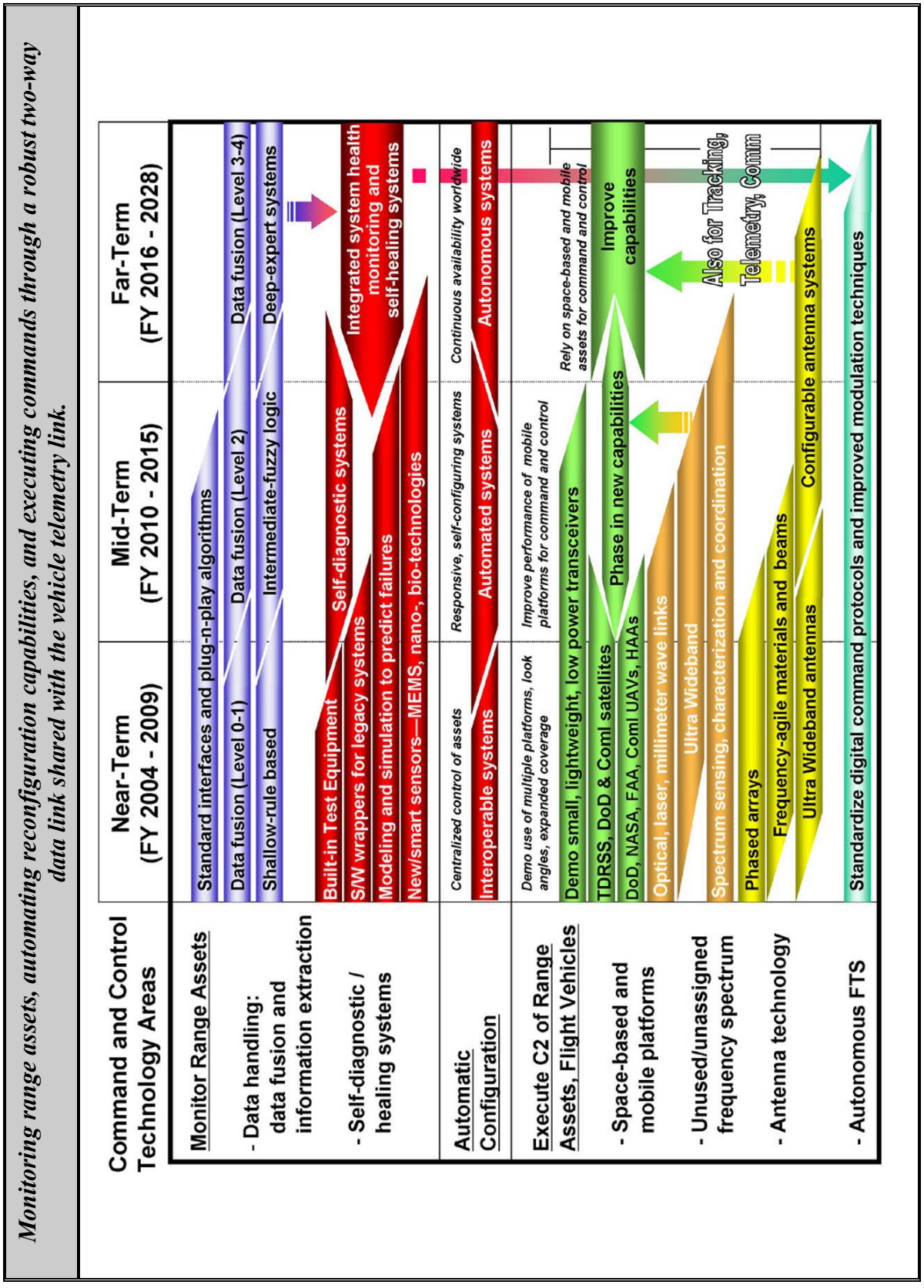

Figure 14. Technology Roadmap for Range Command and Control

DECISION MAKING SUPPORT

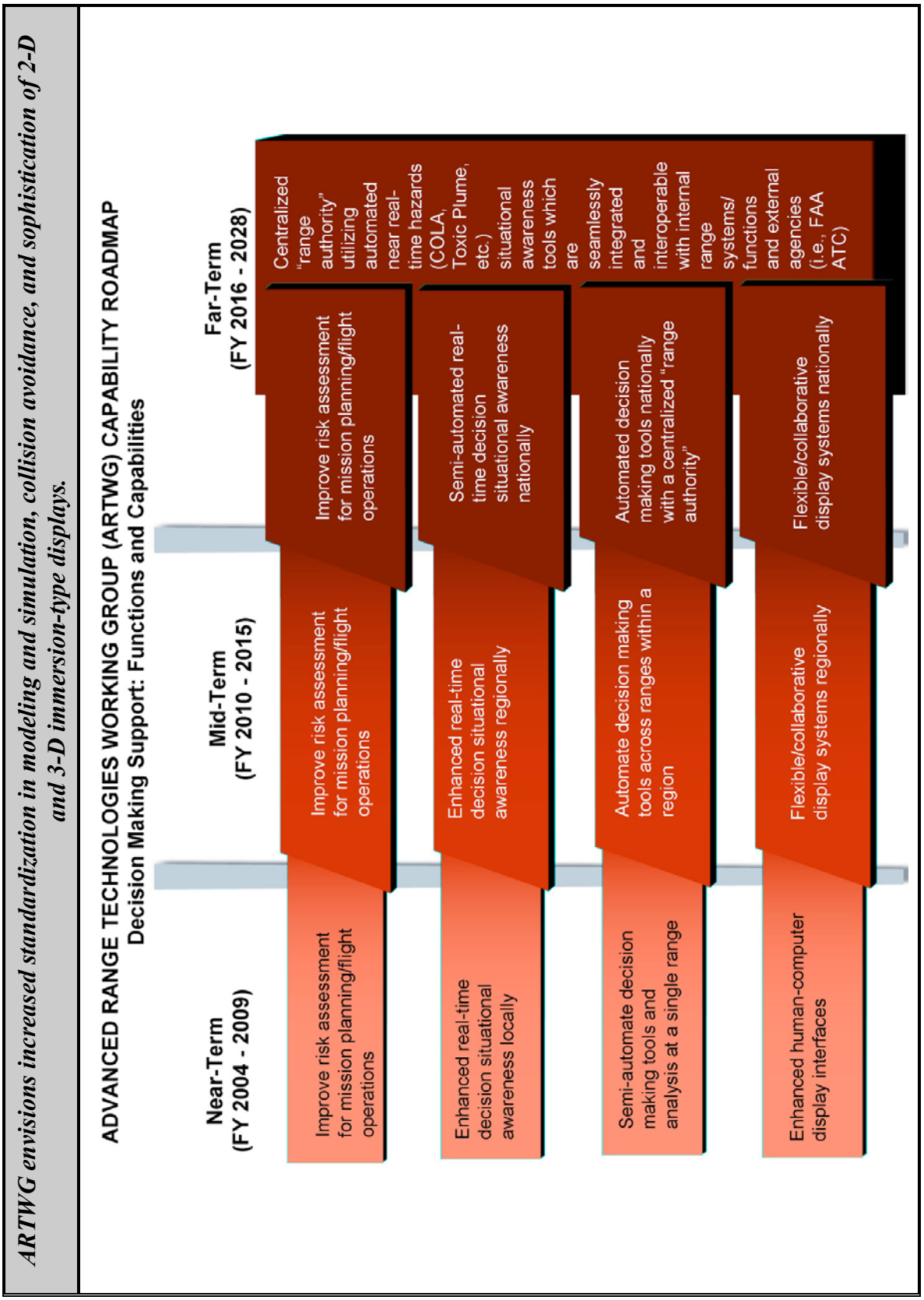

Figure 15. Capability Goals Over Time: Decision Making Support

Higher fidelity modeling and simulation based on enhanced data fusion and extraction capabilities, better integration with FAA space and air traffic management systems, and improved display capabilities.

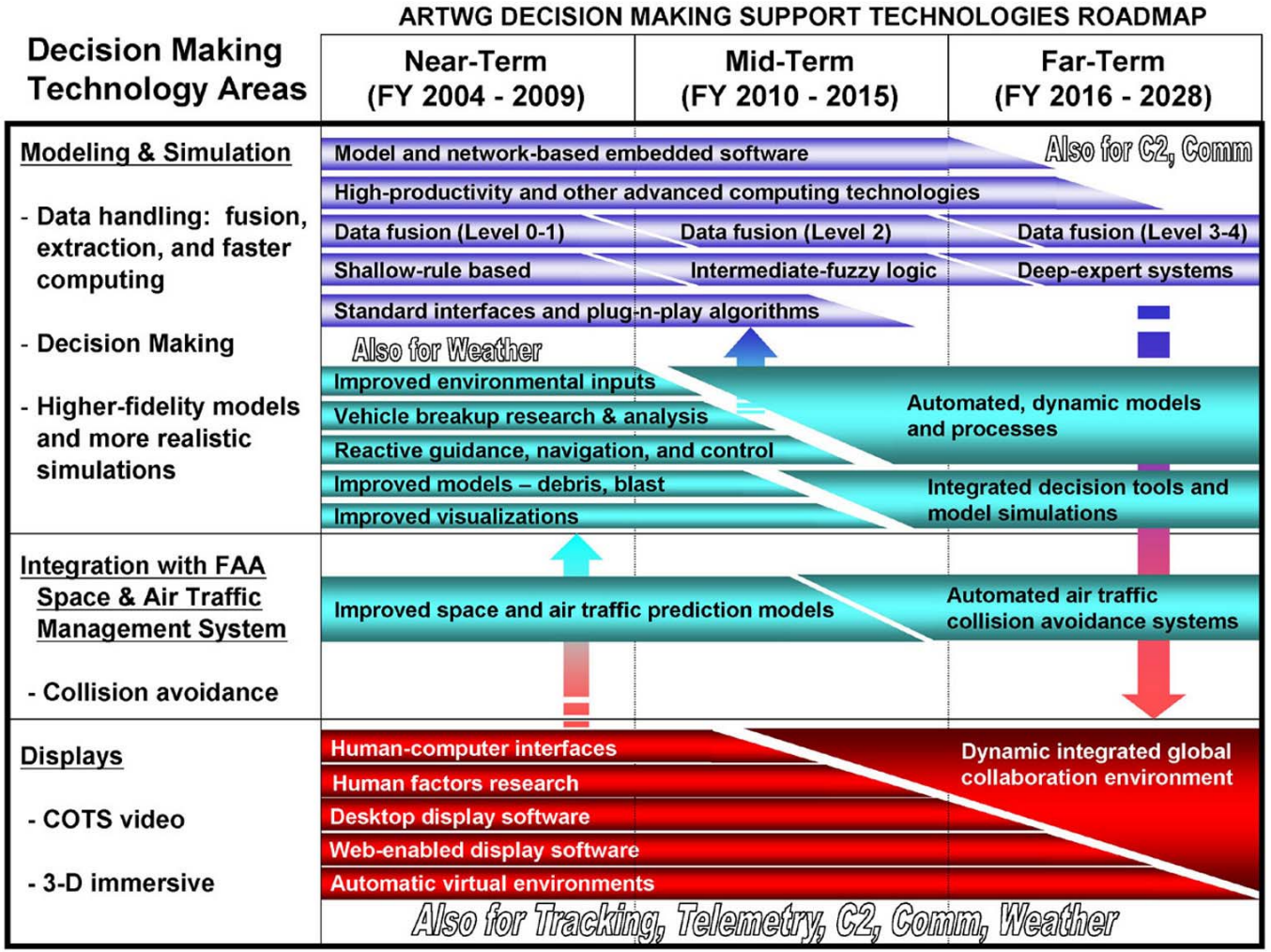

Figure 16. Technology Roadmap for Decision Making Support

PLANNING, SCHEDULING, AND COORDINATION OF ASSETS (PSCA)

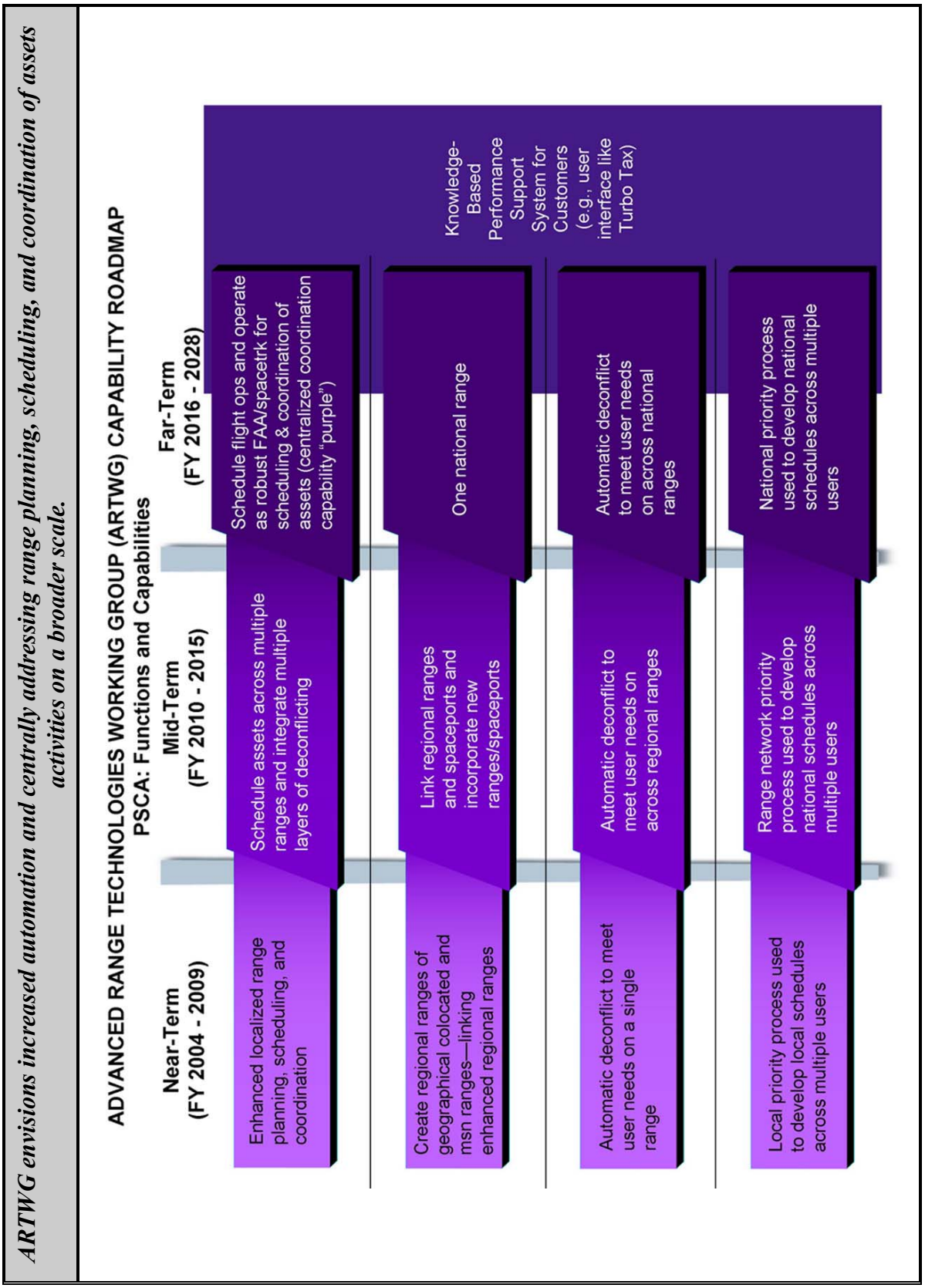

Figure 17. Capability Goals Over Time: Planning, Scheduling, and Coordination of Assets

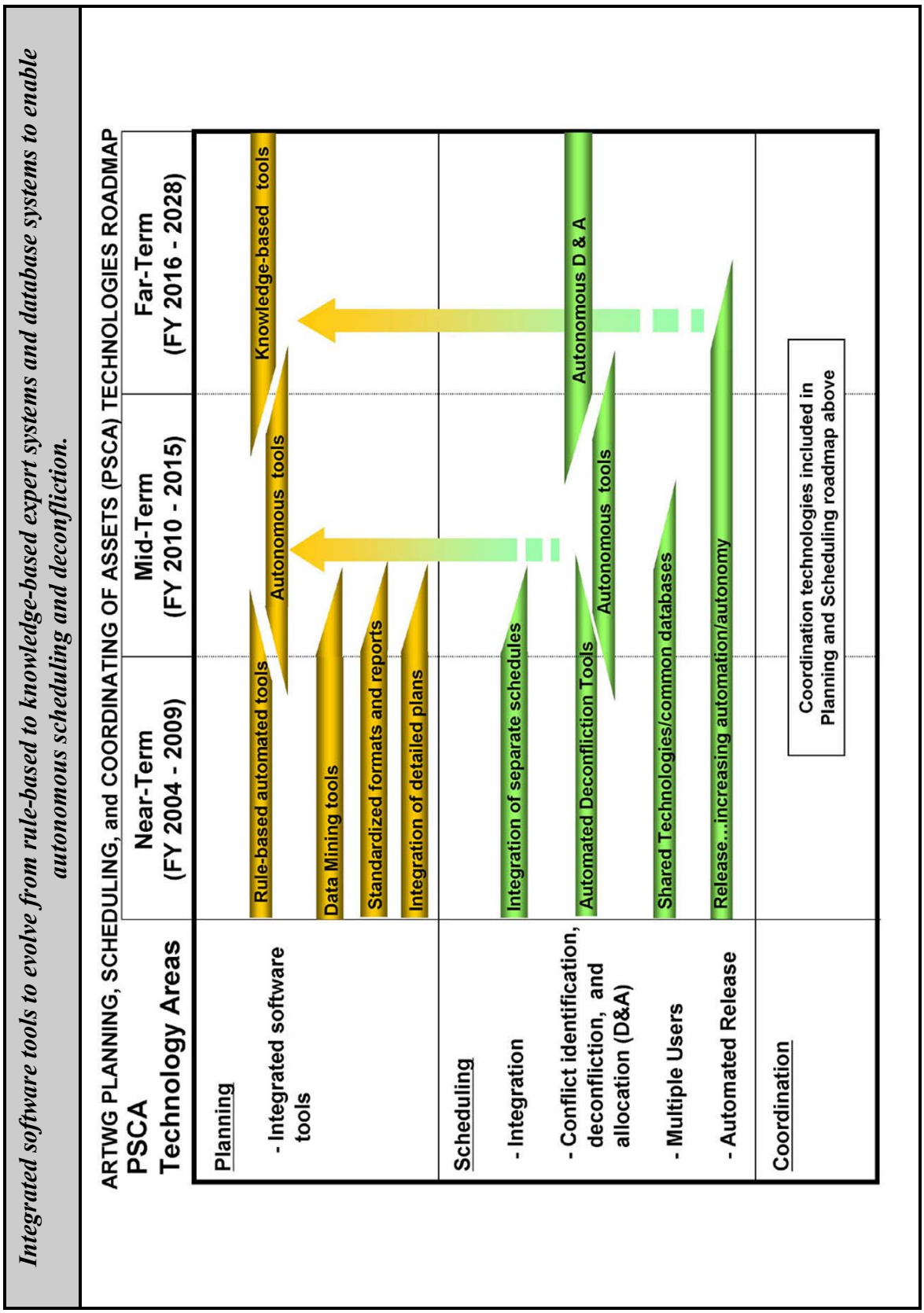

Figure 18. Technology Roadmap for Planning, Scheduling, and Coordination of Assets

WEATHER MEASUREMENT AND FORECASTING

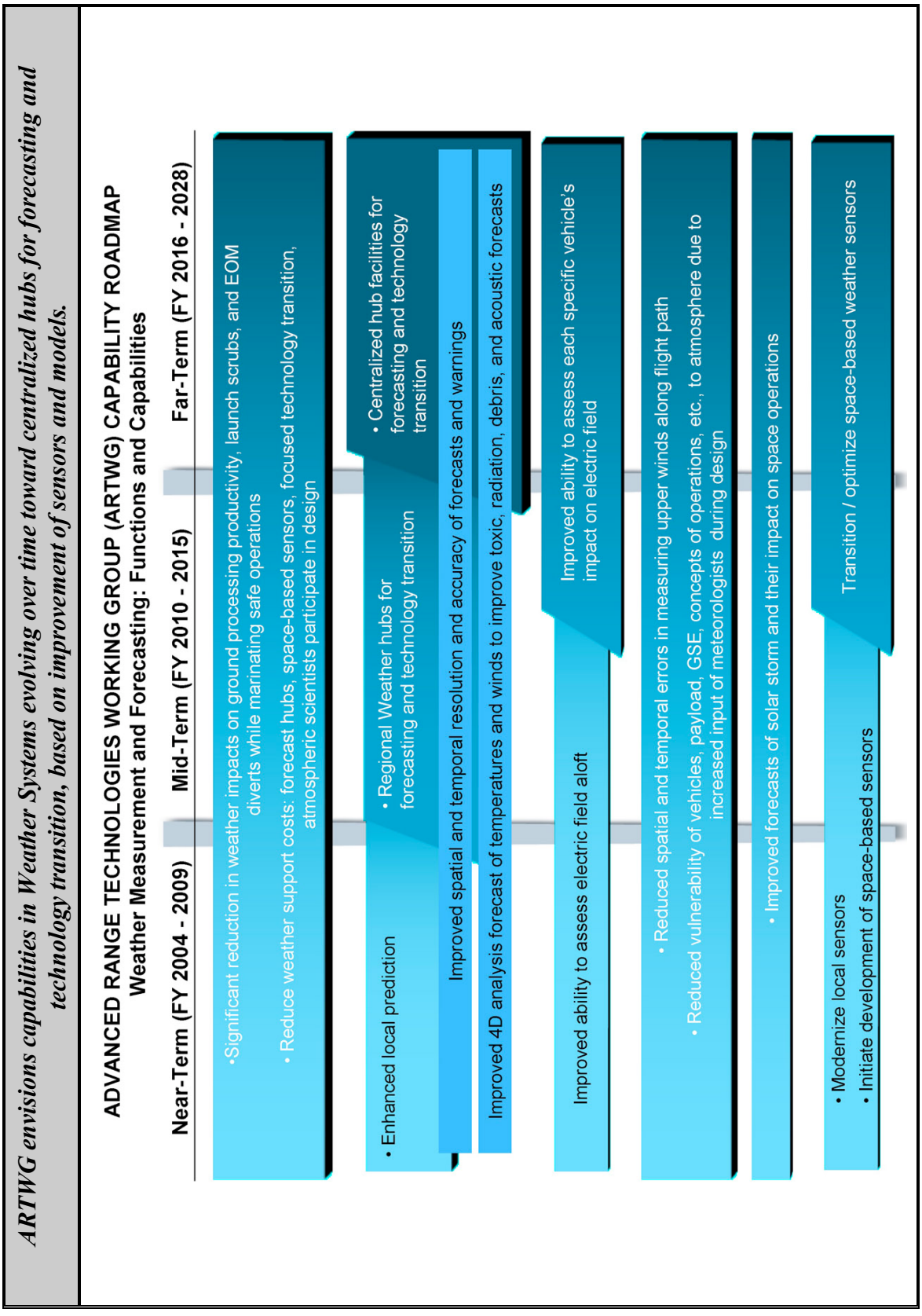

Figure 19. Capability Goals Over Time: Weather Measurement and Forecasting

Better sensors, models, and data fusion, communications, flexible lightning and upper-level wind launch commit criteria, better use of tools and expertise to develop safer vehicles, better mesosphere and space models.

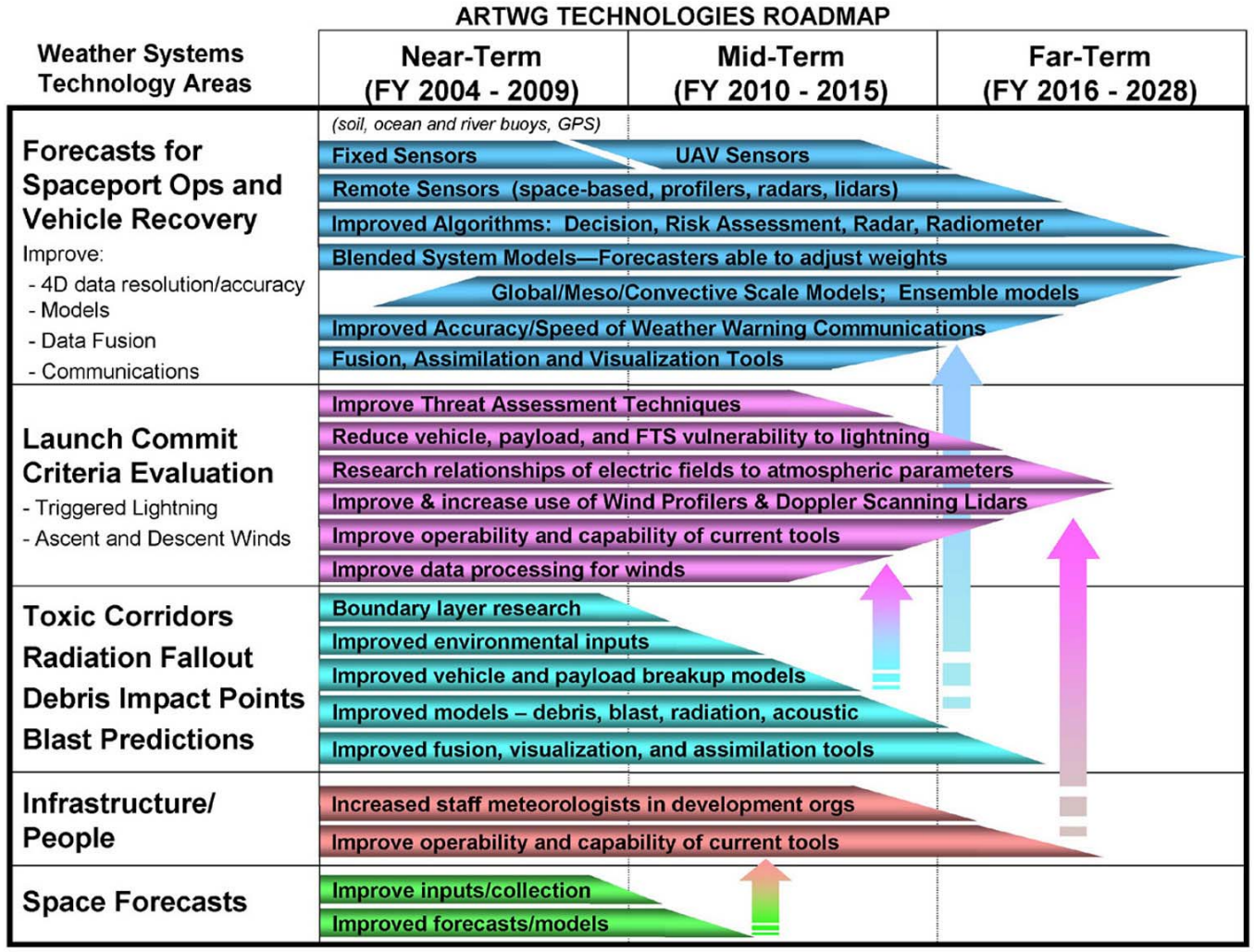

Figure 20. Technology Roadmap for Weather Measurement and Forecasting

CROSS-CUTTING ARCHITECTURE

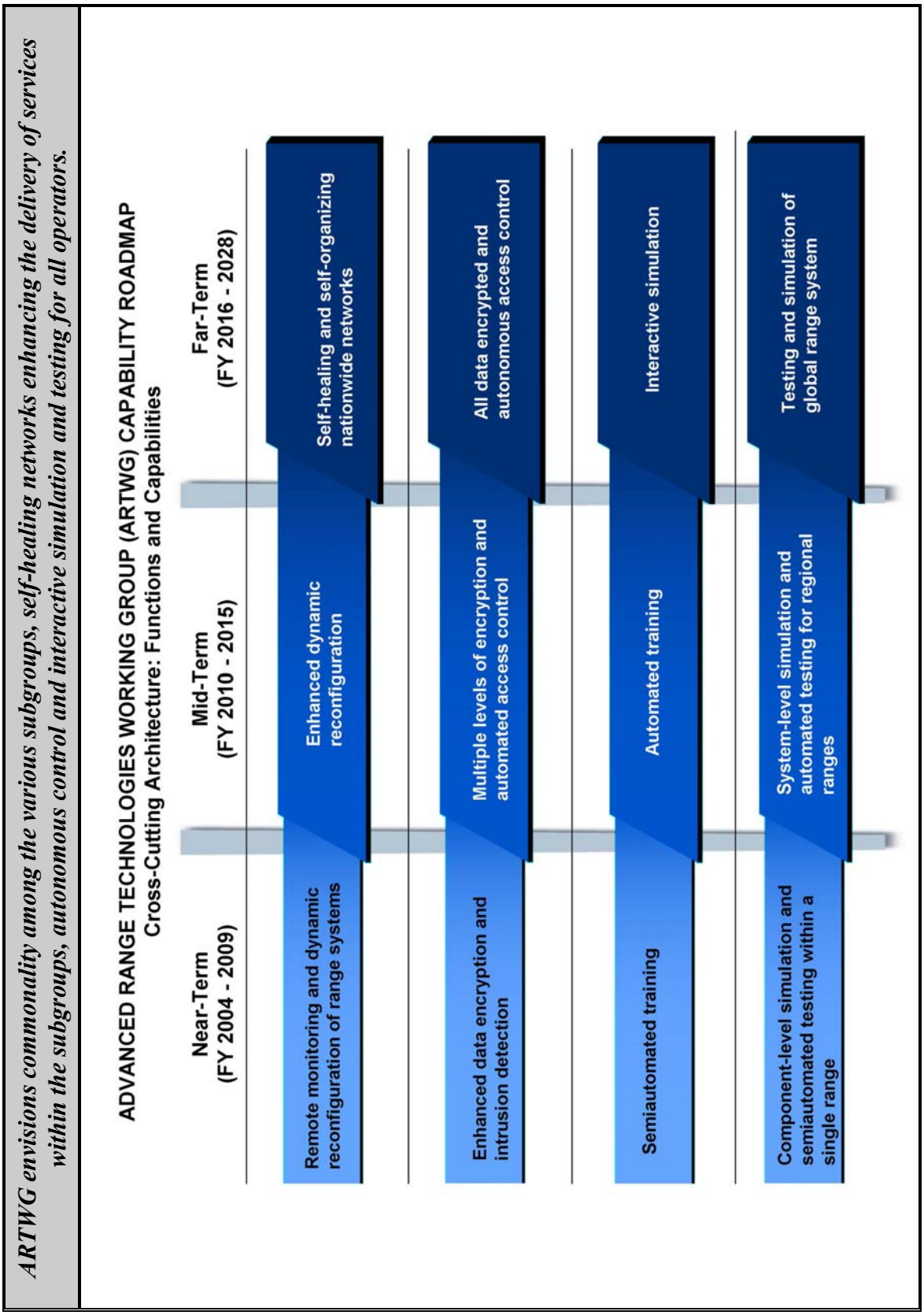

Figure 21. Capability Goals Over Time: Cross-Cutting Architecture (Sheet 1 of 2)

ARTWG envisions cross-cuttng performance measures evolving over time to result in commonality among the various subgroups, self-healing networks enhancing delivery of services, autonomous control, and interactive simulation and testing for all operators.

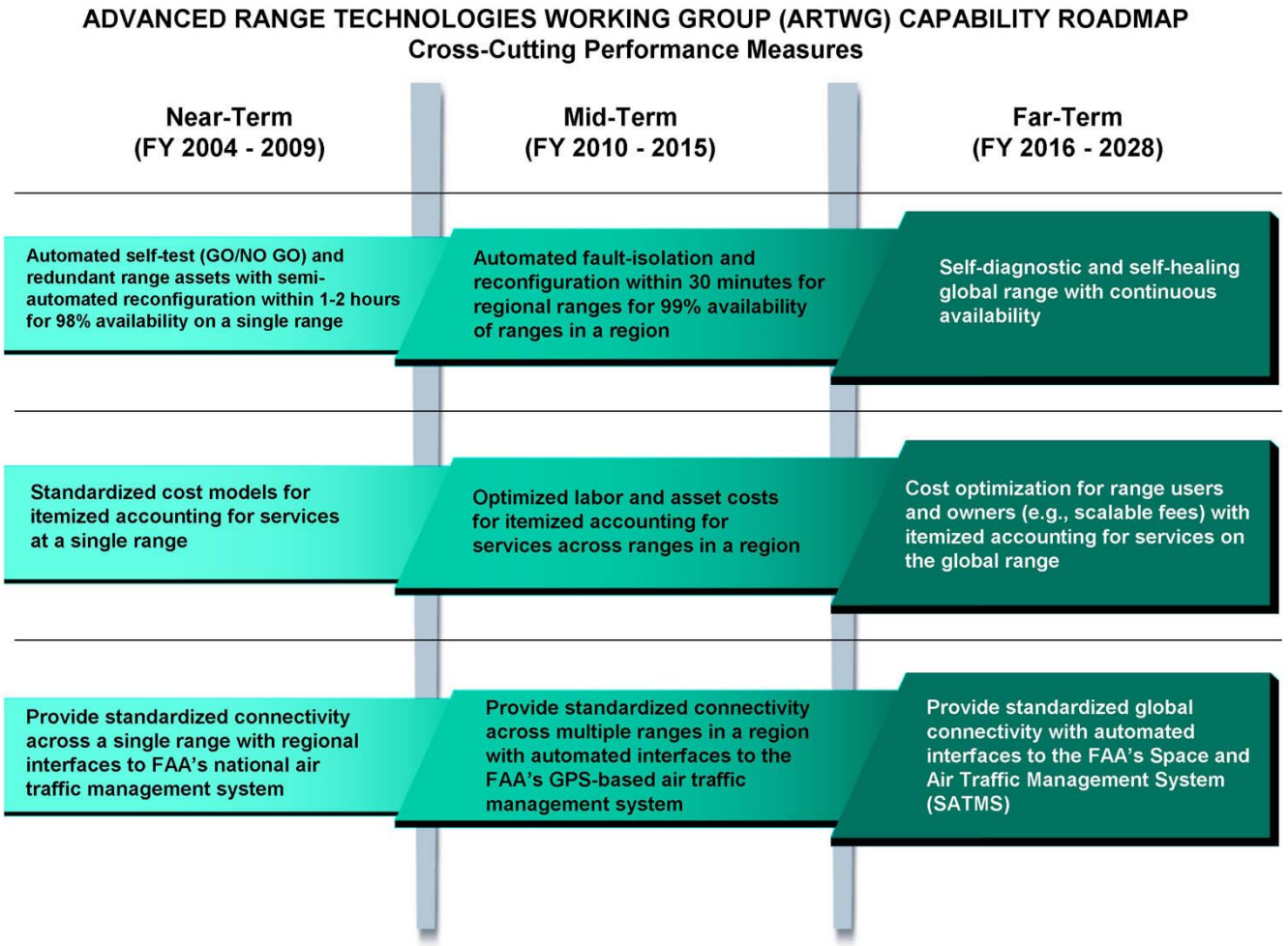

Figure 21. Capability Goals Over Time: Cross-Cutting Architecture (Sheet 2 of 2)

Key technologies for cross-cutting architecture include automated systems, autonomous self-repairing systems, integrated system health monitoring and self-healing, software intelligent agents, data fusion, model and network-based embedded software for testing.

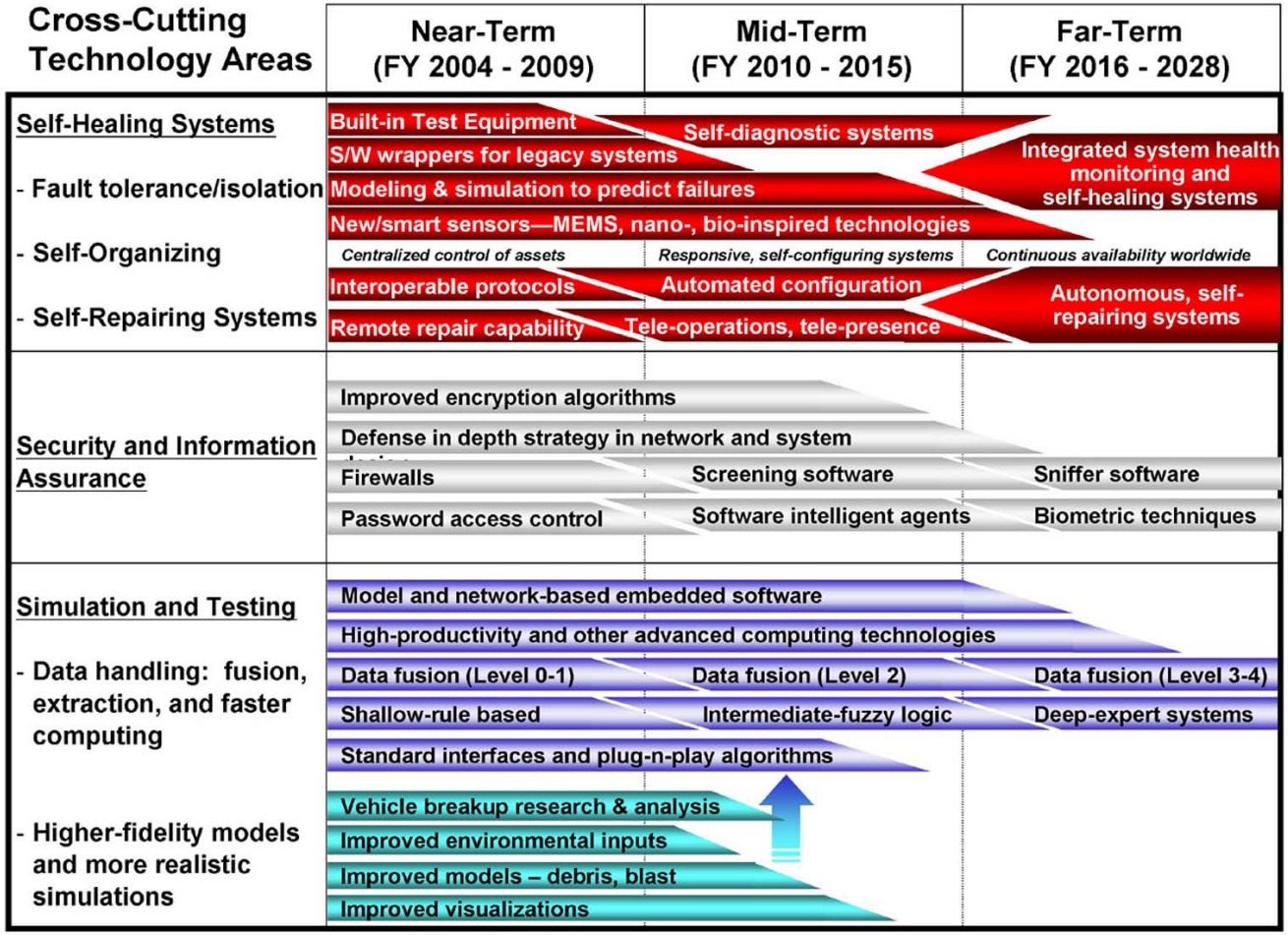

Figure 22. Technology Roadmap for Cross-Cutting Architecture

CONCLUSION AND RECOMMENDATIONS

Under the shared leadership of the USAF and NASA, the ARTWG has carried out the recommendation from the February 2000 interagency report on *The Future Management and Use of the U.S. Space Launch Bases and Ranges* to "develop a plan to examine, explore, and proceed with next-generation range technology development and demonstration." The capability and technology roadmaps presented in this report outline the technologies and demonstrations that should be pursued to enable the development of next-generation range capabilities that would "improve safety, increase flexibility and capacity, and lower costs for reusable and expendable launch vehicles" while also enabling support for emerging and projected test and evaluation missions.

The next step along the path toward developing more capable and efficient next-generation space launch and test ranges should focus on how to "proceed with next-generation range technology development and demonstration," as recommended by the interagency report.

- This should begin with a coordinated interagency effort to pursue the resources and authority necessary to orchestrate and conduct the technology development and demonstration activities outlined in the roadmaps.

- A coordinated interagency program involving multiple Government agencies should be created to direct and coordinate the development and implementation of a coherent overall strategy and plan for the nation's development of a primarily space-centric range capability supplemented by mobile range assets.

The most pressing range support issues that must be addressed and resolved in the near-term include:

- Access to and efficient use of frequency spectrum to support range functions and users.

- Target/miss distance measurement to support increasingly complex and diverse ballistic missile defense testing scenarios involving new geographic areas and multiple flight vehicles.

- Data relay issues associated with the use of satellites, particularly in geosynchronous Earth orbit (GEO), for range and user telemetry, communications, and command and control.

- Operationally responsive range to support rapid range launch and reconfiguration for the Operationally Responsive Spacelift (ORS) Program.

Both within and outside the range community, many opportunities for synergy exist among a variety of ongoing programs and research, development, and demonstration activities. These activities should be leveraged and pursued to enable the spiral development of new range capabilities that will be useful in incrementally improving the capability and efficiency of the nation's ranges. The ultimate goal of these efforts should remain focused on achieving the vision for a next-generation space launch and test range capability.

The following specific opportunities for synergy should be pursued as part of the overall strategy to pursue the technologies and demonstrations included on the ARTWG technology roadmaps:

- NASA, commercial, and DoD UAV technology and development efforts should be leveraged to assist the range community in affordably developing and demonstrating the use of mobile range assets to provide additional capabilities, capacity, geographic coverage, adaptability, and flexibility in providing range support when and where needed.

- Missile Defense Agency, Army, Navy, Coast Guard, and FAA interest in high-altitude airships for area surveillance should be leveraged and pursued as an area for synergistic development and demonstration, ultimately leading to low-cost, multiple-use mobile platforms for range instrumentation and assets.

- The range community should pursue synergistic opportunities to demonstrate new space-based and mobile range technologies and capabilities to provide support during flight test missions involving ballistic missile defense test scenarios and flight test activities being pursued under the joint DoD-NASA National Aerospace Initiative.

- The Defense Information Systems Agency's (DISA) Joint Interoperability Test Command (JITC) efforts to address efficient, interoperable data links and its expertise in interoperability certification could be leveraged by the range community in its efforts to apply technologies, approaches, and techniques to range Command, Control, Communications, Computers, and Intelligence (C4I) systems and capabilities.

- The Joint Advanced Missile Instrumentation (JAMI) program (developing flight and ground systems to track missiles and targets without relying on ground-based radar by utilizing GPS and guidance system data with existing telemetry links and infrastructure) should be viewed by the range community as a significant opportunity for synergistic development of on-board flight vehicle instrumentation to more efficiently interface with range systems, including demonstrations of new technologies and systems.

- DoD's Multi-Service Target Control System (MSTCS) Project (a modular, interoperable GPS-based system with high- and low-rate data links) should be leveraged to develop systems capable of providing precise tracking data for space launch and flight test vehicles as well as target control for vehicles involved in missile defense testing.

- The UAV Battlelab at Eglin Air Force Base (AFB) is pursuing significant developments in digital video data compression technology that should be explored and leveraged by the range community as a means of making more efficient use of frequency spectrum on space launch and flight test ranges.

- The Naval Research Laboratory (NRL) has efforts to develop wide bandgap semiconductor materials, and technologies should be leveraged by the range community to include prototype hardware to demonstrate use of higher frequencies for telemetry, communications, and command and control in conjunction with other range technology demonstration activities.

- The range community should engage with the Transformational Communication Office (TCO) to ensure its plans and programs include future range systems and requirements. This program is intended to remove bandwidth constraints through a new network of high-capacity satellites for use in combination with the Global Information Grid.

- FAA's continued NAS modernization efforts have many similar capability needs and technology development areas such as CNS, weather, and decision support tools. Through related technology needs, the possibility of sharing common assets (radar, communications networks, etc.) and operational dependencies, a common air and space transportation system is expected to evolve.

Advanced Range Technologies Working Group